AIDS

TO

Engineers' Examinations

WITH

QUESTIONS AND ANSWERS.

This work is Dedicated to

VICTOR HAWKINS

AT WHOSE REQUEST IT HAS BEEN COMPILED.

WASHINGTON MULLIN.

See page 203.

AIDS

TO

ENGINEERS' EXAMINATIONS.

PREPARED FOR

APPLICANTS OF ALL GRADES.

WITH

QUESTIONS AND ANSWERS.

A Summary of the Principles and Practice of Steam Engineering.

BY N. HAWKINS, M. E.,

Author: New Catechism of the Steam Engine: Hand Book of Calculations for Engineers; Instructions for the Boiler Room; New Catechism of Electricity, etc.

NEW YORK:

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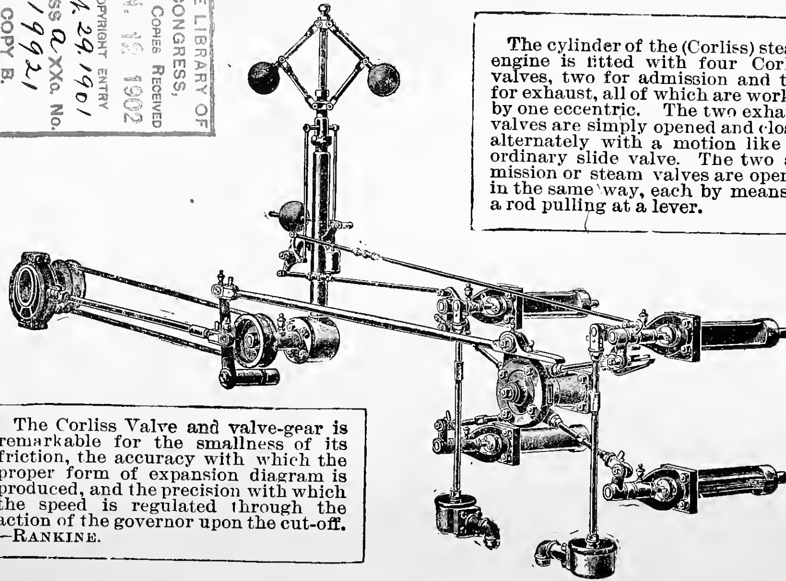
1902.

The cylinder of the (Corliss) steam engine is fitted with four Corliss valves, two for admission and two for exhaust, all of which are worked by one eccentric. The two exhaust valves are simply opened and closed alternately with a motion like an ordinary slide valve. The two admission or steam valves are opened in the same way, each by means of a rod pulling at a lever.



The Corliss Valve and valve-gear is remarkable for the smallness of its friction, the accuracy with which the proper form of expansion diagram is produced, and the precision with which the speed is regulated through the action of the governor upon the cut-off.
—Rankine.

THE CORLISS VALVE. (See pages 150–154.)

INTRODUCTION.

There are three parties to an engineer's license

FIRST. The Applicant.

SECOND The Public.

THIRD The Examiners, or examining board of engineers.

To the applicant the period of an examination is a season of nervous dread and the utmost fitness does not always remove the feeling of anxiety.

Men often operate steam plants satisfactorily who cannot tell how they do it, and a thoroughly practical engineer may make a very poor showing when questioned by an examiner.

It is sometimes still worse when modest applicants are required to write their experience, for in the hands of many men the pen is an awkward tool; hence a very large margin is allowed to men who can demonstrate that they have had the necessary practical experience, even though they may not be able to answer questions off-hand; and those who have become "rattled" under the unusual catechising. are frequently kindly advised by the examiner to "come and try again."

While the tendency in all lines of engineering is toward thorough familiarity with principles, there are still good chances for safe men, who are comparatively unlearned, to acquire experience by actual work in engine rooms.

The relation of the public, to the issue of an engineer's license, is the same as that in which it stands to the issue of druggists and drug-clerk licenses; that is, the fundamental right to protect itself from the criminal ignorance of unworthy pretenders in handling or dispensing dangerous materials.

The community possesses the privilege of passing upon the qualifications of its citizens who propose to manage and control machinery or chemicals which, used without experience or good natural judgment, are liable to cause suffering and loss to innocent persons.

No one now disputes this fundamental principle of common law; and it is a notable fact that the more competent a man is for the performance of an engineer's duties, the more he desires an honest administration of the laws regarding the subject, and a safe standard of qualification.

Relating to the office of an Examining Engineer it may be said that the position is no sinecure, for he should be thoroughly qualified to examine and pass on candidates, so that none but sober, competent and careful men are passed.

As examinations must, perforce, be conducted by practical engineers, it follows that upon engineers, as a class and profession, depend their own standing in the community. If the Examiner is a high-toned, sober, intelligent man, in the course of time the men he passes upon, and to whom he awards licenses, will be very nearly up to his own standard as

a man. It would be worthy of interest to know the history, education and experience of, say, one hundred of the examining engineers of the country; for these men, as models, the thousands of men who come under their contact, will certainly emulate and approach while never passing their standard of excellence; hence the future welfare of steam engineering as a profession and the money income of its members depend almost wholly upon the Examiners.

The test to which Examiners themselves are put before receiving their appointments is very severe, and to have held this appointment is a life-long honor.

In a recent single year's report of the New York City Steam Boiler Inspection and Engineer Bureau, there were one thousand one hundred and sixteen examinations of new applicants for engineer's licenses, of which no less than five hundred and thirty were found incompetent and certificates refused.

Of the five hundred and eighty-six successful applicants, there passed:

On the first examination................	434	
On the second examination..............	126	
On the third examination...............	23	
On the fourth examination..............	3	
		586

In the same year there were:

Certificates, renewed..................	4.597	
" transferred..............	1,383	
New certificates granted..............	586	
Making the total number in force..		6,566

These six thousand five hundred and sixty-six certificates were divided thus:

Certificates of the 1st class..........	1.328	
" " 2d class............	1,498	
" " 3d class..........	3,409	
Fire department engineers............	196	
Permits for boilers only..........	135	
		6.566

And in the same year there were eight thousand four hundred and thirty eight inspections made of steam boilers.

The sum of two dollars for each certificate, amounting to $13,724.00 was collected and paid to the Treasurer of the Police Pension Fund in accordance with the provisions of Chap. 437, Laws of 1885.

In New York City each boiler is numbered in the Records at Headquarters; each Engineer's certificate is likewise numbered, and a heavy fine is imposed for misusing the papers for another's benefit; and in case of the loss even of the papers the fact must be immediately reported at the office of the Examiner, and a fine may be imposed for the carelessness which resulted in the loss of the certificate.

It will thus appear that each license applies to a special steam-plant, of which a full description is kept in the files. When an engineer changes his position he must have his certificate "transferred." By this it will be seen that an applicant must first secure his position; and then his license —if he is found worthy—is usually granted upon the written request of the owner of the steam-plant, who has previously engaged him, and fixed the details of service and compensation.

The certificates are for one year, and on each are printed the following rules:

"Holders of certificates must apply to the officer in command of the Sanitary Company for re-examination and renewal of certificates on the dates of the expiration of the certificate. This date of expiration will be found printed on the face of the certificate.

The certificate allows the person named to take charge of and operate the steam-boiler mentioned, *but no other*, and will be revoked on proof of negligence or insobriety."

HAWKINS'
EDUCATIONAL
WORKS FOR
ENGINEERS

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TO

ENGINEERS' EXAMINATIONS.

The necessary qualifications to secure a license are nearly in the following order:

1st.—Character or general fitness for the trust.

2d.—Knowledge and experience relating to the steam generator.

3d.—Skill in the running of the steam-engine and other machines.

Before the issue or the refusal of a license to an applicant he is examined personally, and alone, by one of the Board, all of whom are practical engineers; and there is no stated list of questions either oral or written.

If a candidate shows by his answers that he is familiar, through actual experience with his duties, and not coached by some one for the mere purpose of obtaining a license, he is entitled to his papers.

Relating to character qualification, it may be said that as the engineer is to be in charge with an almost independ

ent trust of property and life, the Examiner will, before anything else, seek to ascertain something of the habits and moral principles of the applicant. No man, if it is known, who ever yields to intoxication, and no one who is a convicted embezzler, will be granted a license; without question the indefinable marks of an honest man go very far towards securing to him his papers.

The reliable engineer is nearly always a man of thoughtful dignity of manners, as naturally becomes habitual to one under an unceasing weight of responsibility, involving so much; this outward evidence of inward qualities is rightly most favorable to an applicant.

Character is what a man really is, and a good character implies many virtues, such as truthfulness, courage and coolness under sudden danger, a habit of tidiness in person and dress, strict honesty and large-mindedness; all these are to be expected from an applicant for an engineer's papers.

So important is this qualification—of good character—considered, that there are printed on each of the seven thousand licenses issued by New York City the following.

Chapter 643, Laws of 1886. "When, on examination of an applicant, it appears to the satisfaction of the Engineers that he lacks natural capacity, or mechanicel skill, knowledge or experience; or is unfitted by habits of insobriety to perform the required duties in a manner consistent with safety of life, a certificate of qualification will be denied. Renewals of certificates will be refused, and certificates will be revoked on proof of like deficiencies."

For many reasons a good character is the first requisite for the granting of a license, coming even before skill and

knowledge of the business. It is on account of its relative importance that applicants are first required to give an account of their experience in the practical duties of engineer, machinist or firemen.

As to the general fitness of the applicant it may be said that age implying a certain length of experience is necessary; while on the other, extreme age, even with great skillfulness if accompanied by bodily weakness, is a bar to passing. Defective eyesight, an evidence of extreme nervousness, and certain bodily defects, are very potent reasons for withholding consent.

Secondly, the examiner will proceed to ascertain the applicant's knowledge of the steam generator. No applicant wanting in practical experience in the care and management of the steam boiler will be permitted to pass. If there were no liability of steam explosions there would be no need of issuing licenses in stationary engineering service any more than for a license to run wood or iron working machinery, pile drivers, or the thousand and one machines used in modern industry for example, no license is required to run a water-mill, however large, unless it has a steam boiler on the premises

Accidents in steam plants, like the bursting of fly-wheels and breaking of cylinder-heads, even if accompanied by injury and loss of life, cause no uneasiness in the public mind, and carry no personal discredit to the Examiner; but, if a license is granted to an unworthy person, and an explosion of a steam boiler occurs, causing personal injury or loss of life, then the public, through its Coroner's or other juries will

blame the Examiner for being remiss in guarding its safety, as well as the person in direct charge. Hence, the sharpest questionings come in reference to the steam boiler.

While the first element of stress is laid upon character, the second is properly put upon the knowledge of the steam generator, and the greater portion of this book of "aids" will be devoted to the problems relating to its construction, safety and management.

Third will come all these questions relating to the steam-engine, pumps, piping and general knowledge, which go to prove that the applicant is really an engineer (that is, an ingenious person), capable of the position of trust to which he aspires.

So very different in responsibility are the positions required to be filled by the engineer that it is almost always a matter of individual judgment with the examiner as to the fitness of the man for the place ; and in forming this judgment and deciding aright both the discernment and skill of the examining engineer are exhibited.

In the latter part of this work will be found several extracts from city and United States laws, relating to engineer's licenses and examinations. These will, doubtless, form models for other parts of the country, as yet without laws bearing on the subject, as they, one by one, adopt the system of protection found so useful, where it has been tested

CLASSIFICATION OF KNOWLEDGE THE KEY TO SUCCESS.

"*When a man's knowledge is not in order the more he has of it the worse he is off.*"—OLD PROVERB.

This old saying conveys the strange truth that sometimes the more a man knows the more useless is what he knows. It is true notwithstanding its strangeness, and it is true especially in practical steam engineering.

On a certain corner in the Bowery of New York City may be seen a store window packed full of all kinds of cutlery—razors, corkscrews, butcher knives, files, screw drivers, pistols, hammers, boxes of drawing tools and a hundred other things in the hardware line. These are all in one jumbled mass in indescribable confusion and are an emblem of the disorder in the mind of an unapt, blundering, unskillful man in the engine or boiler room. He has the knowledge, perhaps, but it is never available when needed.

Now, on Park Row, a little south, there is a regular hardware store with a stock of goods a hundred times the variety and a thousand times as large as that in the Bowery and yet scores of men and many teams serve hundreds of customers every day and block the sidewalks with the incoming and outgoing loads of their ware, handled in the big many

storied building and all without confusion, loss or hurry. This is also a symbol of another kind of man who has his wide and extensive knowledge well in hand for ready use, who easily may assume with credit the position of chief engineer.

What is the key to success in the management of a steam plant and of personal advancement? It consists in the scientific or orderly arrangement of the various knowledge required to make the experienced engineer.

Not only the chief but the assistant engineer, the oiler and the fireman should strive towards this due classification—as soon as a fact is acquired let it be stored away in its proper place in the mind. Facts about steam with the steam (mental) department—facts about the engine in the engine (mental) department; facts about piping and valves with the pipe and valve (mental) department, etc., etc.

In this way the mind and memory are filled with available knowledge like a well written book with a reference index.

For instance all the various items of information relating to the physical properties of steam should be grouped together in the engineer's mind, or he should know where and when to lay his hands upon needed information relating to this subject. Example: There is a table of steam properties called Regnault's Tables, which show the temperature of steam at the different pressures, the volume per pound in cubic feet at the different temperatures, etc. Now it is not necessary to carry all the figures in one's mind, it is only necessary to know of the existence of the Tables, where they

are to be found—in what book and in what library, and finally to accurately apply the figures to the problem to be decided.

To know these and other fundamental laws is a long step in the science of steam engineering and the remuneration is large to the man who knows and can use his knowledge.

The rudiments of steam engineering can be acquired by about two years of constant application, and close observation, by a person who has a liking for the work. A person who does not like to perform the duties required will never acquire "full competency" for the duties required of a chief engineer, for the reason that he will not have the opportunity.

A system of education that tends to broaden the mind and thus render it capable of dealing confidently with large questions is not only most likely to make the engineer educated under it more respected by those with whom he comes into contact in professional life, but it gives him a wider range of opportunities.

The immense magnitude of modern steam plants and their combination of Steam, Electricity, Refrigeration, Transportation, etc., calls for first class men to manage the complex machinery.

This theme is a difficult although necessary one, and advice relating to it may be summed up thus—

FIRST. Do not "lumber" the mind with useless matters.

SECOND. Be sure of the truth of each single fact.

THIRD. Store the fact or item of information away in the mind with other kindred items relating to the same department of engineering.

To make the most of oneself is a problem which has been answered by the word concentration. Keep close to one line of advancement and be content to be ignorant of some things in order to know thoroughly some others, The path being chosen, then let the advance be persistent and unceasing. It was thus that Stephenson produced such results in locomo tion, and Watt such wonders with the steam engine.

This persistent industry is not irksome. It carries its own reward, and the results are definite and sure.

> "One step and then another,
> And the longest walk is ended;
> One stitch and then another,
> And the largest rent is mended.
> One brick upon another,
> And the highest wall is made:
> One flake upon another,
> And the deepest snow is laid.

THE STEAM BOILER.

While the shapes and forms in which steam generators have been constructed are many, they all agree in one point —they are closed vessels strongly made so as to withstand an internal pressure of considerable force.

In engineering terms this force is called the steam pressure and it varies from 5 to 300 lbs. per square inch. It is the first rule in the design of steam boilers to provide against this varying internal force.

While the sphere is the strongest form of vessel to resist internal pressure, there are many practical reasons which prevent its being used for the purpose. Next to the sphere the cylindrical form is the simplest and strongest, and is now universally adopted.

The steam boiler has two essential parts, the furnace which contains the fuel to be burnt and the boiler containing the water to be evaporated. Within the boiler there must be steam-room as well as water space—outside there must be heating surface and a chimney or other apparatus to convey away the waste products of combustion.

Questions and Answers Relating to Materials for Boilers.

Ques. What is the meaning of Tensile strength when applied to rivets, braces and boiler plates?

Ans. It is that amount of force—usually expressed in pounds—which, steadily and slowly applied in a straight line, just overcomes the cohesion of the particles and pulls it into separate parts

Ques. What is the meaning of shearing strength?

Ans. It is that amount of force—usually expressed in pounds—which, if steadily and slowly applied to the rivet, at right angles to its axis, causes it to separate in parts, which slide over each other. This separation is nearly always at right angles, and in common language is called "shearing off the the rivets."

Ques. What is the meaning of elastic limit?

Ans. This is the point to which steel or iron can be stretched out, and from which the metal will return to its original position. When steel is pulled beyond its limit of elasticity, it does not return to its old place; the "bagging" of a burnt sheet over the fire is an example of the plate having been stretched beyond its limit of return.

Ques. What is the meaning of ductile?

Ans. The material is "ductile," when it can be extended by a pulling or tensile force and remain extended after the force is removed; the greater the permanent extension the more ductile the material.

Ques What is the meaning of "tough" when applied to iron or steel?

Ans. The material is said to be tough when it can be bent first in one direction and then the opposite direction without breaking or cracking. The greater the angles it bends through (coupled with the number of times it bends) the tougher it is.

Ques. What is the meaning of malleable?

Ans. This is the term applied to iron or steel when it can be extended by hammering or rolling without cracking and remain extended; the more it can be extended without fracturing, the more malleable it is.

Ques. What is weldable iron or steel?

Ans. This is the term which is applied to the material if it can be united when hot by hammering or pressing together the heated parts. The nearer the properties of the metal after being welded are to what they were before being heated and welded, the more weldable it is.

Ques. What does homogeneous mean when applied to boiler plates?

Ans. This word describes material of the same structure and nature; where the grain or fibre of the plate is the same in every direction.

Ques. What is the meaning of cold-short iron or steel?

Ans. This is a name given to the material when it cannot be rolled or hammered, or be bent when cold without cracking; such a material can be worked or bent when at a great heat, but not at any temperature greater than that assigned to dull-red.

Ques. What is the meaning of "hot-short?"

Ans. This is when the material cannot be easily worked under the hammer, or by rolling at a red-heat, at any temperature which is assigned to a red heat, without fracturing or cracking, such a material may be worked or bent at a less heat.

Ques. What is the meaning of elongation of metals?

Ans. The amount of stretching usually expressed in lbs. which a test piece will bear, due to a steady and slowly applied force before it is pulled into parts.

Ques. Describe the qualities which should be possessed by a good boiler-plate?

Ans. The plate should not be too large, and should have been satisfactorily tested at the mill by suitable bending tests, and by the testing machine, each sheet being marked with the maker's name, with the figures showing what tensile strength it had stood in the test.

Ques. Repeat the answer, using the definitions for boiler materials in their proper places?

Ans. The material should be *homogeneous*, and of suitable *tensile strength* and *elongation*, best suited for the purpose, having an *elastic limit* that will ensure the boiler being reliable; it should be *tough* and *ductile*; the material should be *malleable*, and in some cases *weldable;* that which is of a decidedly cold-short or hot-short nature should be avoided.

Ques. What is steel?

Ans. Steel is iron with a mixture of carbon or an alloy of iron—the alloy being principally carbon steel; can be melted like cast iron and welded like wrought iron. There are hard and soft steels, according to the process of production and proportion of alloy.

Ques. What is iron?

Ans. It is one of the original substances of which the globe is composed. There is very little pure iron, it being nearly always found combined with other things. Wrought iron is iron with the impurities worked (or wrought out) and thus rendered soft and malleable, ready to be beaten by the hammer into any desired form or rolled into thin plate.*

Ques. What is the tensile strength of steel and iron?

Ans Of iron according to the table, 50,000 to the square inch average—of steel about 70,000 lbs.

* NOTE. A bar of iron worth $5.00, it is stated, is worth $10.50 when made into horse-shoes, $55.00 in the form of needles, $3,285 in penknife blades, $29,480 in shirt buttons, and $250,000 in balance springs of watches.

Ques. What is the difference between steel and iron?

Ans. The steel in ordinary use is an alloy of iron which is cast while in a fluid state into a malleable ingot. To be steel it must be malleable and the product of melting or fusion. This definition excludes pig-iron which is fused or melted, but not malleable; and wrought iron which is malleable but not fused or melted.

Ques. What is an alloy, define it?

Ans. An alloy is a mixture or compound of two or more metals. Ex.: two parts of tin and six parts of lead is "an alloy" suitable for fusible plugs and which melts at 380° fahrenheit. To alloy is usually to reduce the quality of one of the parts, and the least valuable is sometimes called "an alloy."

Questions and Answers Relating to the Expansion and Contraction of Steam Boilers.

Ques. When a boiler is in use what is the effect of heating and cooling it?

Ans. The heat expands and enlarges the whole structure, and it should be so constructed and set in the brick work, that this change in form may be as uniform as possible—one part equally with another.

Ques. Does the cold contract the boiler?

Ans. Yes, and the process of enlarging and contracting is a continual process, as long as the boiler is making steam.

Ques. What is the effect of unequal expansion and contraction?

Ans. It is a severe test of the strength of the boiler, the tubes or flues expanding lengthwise with a force sufficient to tear the heads out of the boiler.

The smaller the proportion of the surface of a boiler that is exposed to the heat, the more active will be the effect of the expanding and contracting forces, and in the case of boilers, set more than half exposed to the influence of the atmosphere, the power exercised by the expansive heat of the fire below and the contraction due to the low temperature above, are almost enough to tear the boiler to pieces.

Ques. Is any more to be said upon this?

Ans. It is the unequal expansion of the shell and tubes that really does more injury to a steam boiler than the expansion and contraction due to changes in the pressure of steam; the leakage and cases of rupture that so often occur in the lower seams and along the bottom of horizontally fired boilers are unquestionably due to these causes; in very many instances forced firing in getting up steam on first starting the boiler is to blame.

Ques. Is the force of expansion and contraction known so that it can be "nearly" calculated?

Ans. Yes, iron will exert a strain of 150 pounds per square inch for every degree of temperature. Suppose iron has been heated to 350 degrees and

cooled down to 60 degrees; if it is securely riveted or otherwise fastened it will be cooled $350° - 60° = 290° \times 150 = 44,500 = 22\frac{1}{4}$ tons, on every square inch of section.

Ques. Name an instance where this force is likely to be dangerously exerted?

Ans. Where the tubes are placed very near the bottom of a boiler, in which case the pressure is all on the lower side of the heads and the plates that keep them together; it is not unusual for these plates to be ruptured or the seams sprung underneath, causing troublesome and often dangerous leaks.

Ques. How are these difficulties to be avoided?

Ans. To avoid the injuries so often caused to boilers in this manner, it is necessary, therefore, to exercise great care in raising steam in new boilers or those that have been blown out and allowed to cool down. The fire should be raised moderately and gradually, and the boiler moderately filled with water, so that the increase in the temperature may be gradual. In cooling off a boiler the same care must be exercised; nor should the furnace doors be suddenly thrown open or any other proceeding taken that will result in suddenly lowering the boiler temperature, a rapid decrease in the heat being quite as bad for the safety and durability of the boiler as the immoderate and unequal increase above referred to.

BOILER BRACES AND STAYS.

Portions of boiler shells which are *flat*, or which otherwise deviate from the round or egg shape, are necessarily strengthened by means of stays or braces, against the enormous outward pressure caused by the steam.

The only forms for the shell of boilers which are safe against bursting by internal pressure, without the aid of stays, are the cylinder and the sphere or egg shape.

The tubes which extend from end to end of the tubular boiler, it has been proved, furnish sufficient holding power to amply stay the part of the head to which they are attached and also two inches above the upper row of tubes.

The flanges of the head being securely united to the shell, and being also curved or dished, it may likewise be safely assumed that no braces need be provided for that part of the head which lies within three (3) inches of the shell.

The part of a horizontal tubular boiler which needs to be braced therefore consists of a segment of a circle whose circumference lies three inches within the circle of the shell and whose base is two inches above the upper row of tubes.

Thus in a 6-foot boiler, whose upper row of tubes is 26 below the top of the shell, the part of the head which requires bracing consists in a segment of a circle, the diameter of

which is 60 inches and the heighth of which is 21 inches; 21 inches being the measured heighth, 26 inches less the 3 inches supported by the flange and the 2 inches supported by the flues.

Each square inch of this flat surface must be practically supported by the braces, owing to the thinness of the plates, of which the boiler heads are constructed ; and large allowance must be made for weakening caused by the age and use of the boiler.

Questions and Answers Relating to Boiler Braces and Stays.

Ques. What are some of the names of boiler braces and stays ?

Ans. Crowfoot-brace, jaw-brace, head-to-head-brace or through braces, gusset-stay.

Ques. What are through braces ?

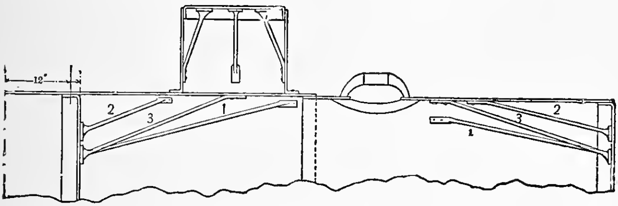
Ans. The same as head-to-head braces, *i. e.*, they pass from one end of the boiler to another.

Ques. What is the crowfoot brace ?

Ans. This is sometimes called the "solid brace" because it is made of one piece of iron with both ends "flanged out" for the purpose of riveting to both the shell and head.

Ques. What are radial braces ?

Ans. These include the crowfoot and braces attached to T iron, and so placed as to run back to the shell in a direct line from the head fastening, at a proper angle.



Ques. What is the difficult problem in arranging the braces inside a steam boiler ?

Ans. It is of allowing access to the boiler for examination and still to properly arrange the braces so that each shall bear its due proportion of load.

Ques. Of what material should braces be made ?

Ans. Of the best iron, without weld, and should be, where threaded, upset for six or eight inches from the ends, so that when these ends are threaded the diameter at the bottom of the thread shall slightly exceed the diameter of the brace.*

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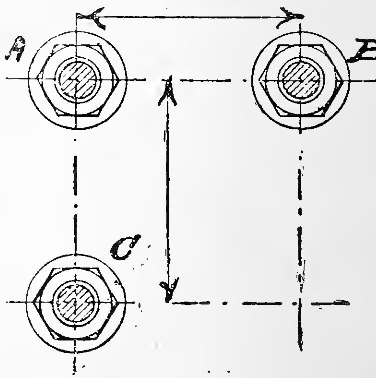
* With radial bracing greater strength is obtained by increasing the number of the braces. With through braces, on the other hand, increased pressure is provided for by an increase in the size of the braces. This is an important consideration; for braces that at 100 pounds pressure sustain a stress of 7,500 pounds per square inch, would not be proper if the boiler were to carry 125 or 150 pounds. The braces should always be proportioned to the surface they have to sustain, and to the pressure of the steam. It may seem needless to refer to so obvious a fact as this, but our experience has shown that too little attention is sometimes paid to it, and hence we feel called upon to urge its importance.—*The Locomotive, Feby., 1894.*

Ques. What stress is allowed on boiler stays?

Ans. The greatest stress to which a boiler stay should be exposed is 6,000 lbs. per square inch of section* at smallest part of stay if made of iron and but little more if made of unwelded steel.

Ques. How do you find the absolute stress or strain on the flat surface of a steam boiler, which is carried by the stays?

Ans. Choose three stays at three corners of a square—multiply the sides in inches and the result is the number of square inches of surface depending upon one bolt or stay for supporting strength.



Ques. Give an example.

Ans. Suppose the stays measure 5 inches from center to center each way with steam at 60 lbs., then:

$5 \times 5 = 25 \times 60 = 1,500$ lbs. borne by 1 stay.†

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* This is the U. S. Government rule—$\frac{1}{10}$ to $\frac{1}{12}$ the tensile strength of the iron or steel used for braces is a safe rule to follow. Many State and City Ordinances allow 7,500 lbs. net stress.

† The cut exhibits more clearly the process. Measure the distance from A to B in inches and from A to C. Multiply by steam pressure.

Ques. How do you ascertain the number and size of the stay bolts to be used on a flat surface in a boiler?

Ans. By finding the total pressure on the unsupported portion and dividing it by the number of stays, each of which should be strong enough to bear its proportion.*

Ques. In examining the interior of the boiler, which should be done periodically, what are some of the defects for which you would be on the lookout?

Ans. For slack braces, for pins missing from the braces, and also to see that none of the braces have more than their due share of strain, and for leaky socket-bolts.

Ques. What else would you particularly look for?

Ans. For defective riveting, defective heads to the rivets, and for broken and loose stays and braces.

Ques. When defects are found who is the best party to make the repairs?

Ans. An experienced boiler maker.

Ques. If no good boiler maker was available what would you do then?

Ans. I would run no risk but wait until one could be had—unless I myself was capable of making a temporary repair, and then I would try and prove myself an engineer worthy of my position.

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* The stays should be well fitted and each one carefully tightened and as far as possible each stay in a group should have the same regular strain upon it.

Ques. When a new boiler is put into service and it begins to exhibit signs of distress and leakage after being fired up for a few days or weeks, what is usually the cause?

Ans. It is probably the effect of overstraining.

Ques. What is the cause of this?

Ans. Frequently the end plates are too thick or too rigidly stayed, thus preventing the plate from slightly yielding or "breathing" in sympathy with the lengthening and shortening of the flue tubes, constantly taking place with each variation of temperature.

Ques. What remedy is there for this?

Ans. That is a boiler-maker's job, and it is sometimes done by re-riveting the gussett stays which hold the ends and sides of the boiler together.

Ques. Name other things causing overstraining?

Ans. Overheating the plates, resulting from the use of impure water—this is a very frequent cause of the failure of comparatively new boilers, the deposits cause uneven expansion and contraction. Again, the presence of oils in the boiler, admitted with the feed water when taken from the hot well of a jet condensing engine, or admitted with the steam from the cylinders. This, especially where the water contains carbonate of lime, is responsible for a great deal of the trouble arising from straining.

Questions and Answers Relating to Incrustation and Scale.

When steam is used through the cylinder or heating pipes, all of the impurities, existing in nearly all water, remain to vex the engineer, to impede the action of the generator, and to ultimately even destroy it. For instance, a 150 h. p. boiler will evaporate at least 30,000 lbs. of water in each day of ten hours, and in a month, say, 400 tons. In a comparatively pure water there would be 100 lbs. of solid matter in that quantity, and in many kinds of spring water as much as 2,000 lbs., and all this remains after the steam is removed. In some "river waters" such has been the condition of the interior of the steamboat boilers that it has resembled "mush" in consistency.

The impurities are simply foreign bodies, which have no legitimate place in the boiler, and are to be expelled as dangerous foes.

The sediment remaining after the extraction of the steam forms scale; and the presence of scale or sediment in a boiler results in loss of fuel, burning and cracking of the boiler, predisposes to explosion, and leads to extensive repairs. It is estimated that the presence of 1-16 inch of scale causes a loss of 13 per cent. of fuel, ¼ inch 38 per cent., and ½ inch 60 per cent.

Ques. What effect does the accumulation of scale on the interior, and of soot on the exterior of a boiler, have upon the economy of the boiler ?

Ans. The result is to largely increase the amount of fuel consumed, frequently as much as one-fourth in cases of bad scaling.

The most common defects produced are serious leakage around tube ends, incrustation and scale, deposit of sediment, external corrosion, internal corrosion, and defective pressure gauges.

Ques. Is scale all of one kind ?

Ans. No. The nature and hardness of the scale depend upon the kind of substance held in solution and suspension by the water in the boiler.

Ques. What general course is the best in dealing with the sediment ?

Ans. It is more profitable to soften and filter the water than to trust to blowing out or dissolving the sediment and scale after it is there.

Ques. What is the action of a scum-cock ?

Ans. Nearly all foreign matter held in solution in water, on becoming separated by boiling, rises to the top in the form commonly called *scum*, and every boiler should be provided with means for blowing out water from the surface in order to remove the fine particles of foreign matter floating there ; as, if

not removed the heavier particles will be attracted to each other until they become sufficiently dense to fall to the bottom, where they will be deposited in the form of scale.

Ques. Can a mixture be made to use in a great majority of cases of scale.

Ans. One that has been strongly recommended is made up of 40 lbs. of sal soda, to which is to be added 5 lbs. of catichu and 5 lbs. of salamoniac—one lb. of the mixture to be added to each barrel of water used, until the scale disappears, when the use of sal soda alone is all that is necessary.

Ques. Can one preparation be made that will be beneficial in all cases of deposited sediment?

Ans. No. This is owing to the variety of chemical matter contained in water, and the varying quantities existing in the steam generators, to say nothing of the different temperatures in which the "compound" may be expected to operate.

Ques. What is essential in the design of a boiler in reference to the sediment?

Ans. It is absolutely essential to the successful use of any boiler, except in pure water, that it be accessible for the removal of scale, for, though a rapid circulation of water will delay the deposit, and certain chemicals introduced into the water may lessen it, yet the only certain cure is periodical inspection and mechanical cleaning.

Questions and Answers relating to the Steam Boiler.

Ques. What are the principal forms of steam generators ?

Ans. There are three, stationary, locomotive and marine, which terms explain for what uses they are built.

Ques. Name some of the boilers which come under the heading of stationary.

Ans. The Horizontal Plain Cylinder; the Two Flue; the Horizontal Tubular; the Water-tube; the Cornish; the Sectional, etc.

Ques. Which form is the one most largely in use ?

Ans. The Horizontal Tubular.

Ques. What are its special advantages ?

Ans. This type is the result of many years of experiments, and aside from a liability to an occasional explosion, has proved itself best adapted to the wants of steam users.

Ques. Name some of its special "points" of advantage.

Ans. It is the cheapest in construction; it is cylindrical; it encloses the greatest volume of water and steam with the least material; it is very accessible for cleaning out and it resists internal and external strains with equal excellence.

Ques. What is the peculiar difference between water tube boilers and others ?

Ans. The fact of the small tubes being used for holding the water—the distinction is expressed by denominating the older type 'fire tube" boilers.

Ques. Name the advantages claimed for water tube boilers.

Ans. The principal claim for superiority is that they are supposed to be safe from disastrous explosions. This is owing to the small size or diameter of the tubes of which they are built. 2d.—They are quick "steamers." 3d.—Are accessible for repairs and cleaning and are easily transported—being constructed in small sections—and easily set up.

Ques. What are the known disadvantages of the water tube system ?

Ans. While they make steam quickly, the pressure as quickly subsides, owing to the small reserve in the water space; the use of cast-iron used in their construction has frequently worked badly in practice and they are said to be more liable to "prime" than other forms.

Ques. Has any particular form of steam boiler proved itself absolutely the best ?

Ans. No. Tests prove that a square foot of heating surface in both systems, if properly set and with an equally good draft, evaporates nearly the

same number of pounds of water to a pound of coal.

Ques. What is the essential peculiarity of the marine boiler?

Ans. By U. S. Law all marine boilers must be constructed so that they are fired internally. They are not allowed to be "set" in brick work.

Ques. What is the essential peculiarity of the locomotive boiler?

Ans. In that it has the steam engine attached to it, thus making it, as it were, a combined engine and boiler, which, with the steam-blast invented by Geo. Stevenson, forms as near a live thing as is known in the world, of man's creation.

Ques. About how many pounds of water can be evaporated per pound of coal by an ordinary boiler?

Ans. From seven to eleven pounds, depending upon the quality of the coal, the draught, and the thickness of incrustation on the interior of the boiler and amount of soot and ashes on the shell and in the tubes.

Ques. What part of the steam boiler is the strongest?

Ans. The strength of a boiler is only that of its weakest part; hence boiler makers are always studying methods of perfecting the structure so that every portion has the same resistance.

Ques. What is the great cause of steam boiler explosions?

Ans. Weakness in the boiler to withstand the pressure. When a boiler is strong enough to hold the steam it will not explode.

Ques. What produces this weakness?

Ans. Generally by overheating the plates, caused by shortness of water. When the sheets are heated to a certain point they lose their power of cohesion and become very weak. This causes them to bulge or come down; and where the pressure is suddenly increased by pumping in water, an explosion takes place.

Ques. What other causes can you name which are liable to produce an explosion?

Ans. Excessive pressure, beyond the limit for which the boiler was designed; by bad workmanship in punching and riveting the sheets; by bad material used in the construction of the boiler; by the collection of mud and scale; and by bad design in which the boiler may not be properly strengthened by stays and braces.

Ques. Have you any particular "theory" as to boiler explosions?*

*A press despatch from Haverhill, Mass., tells of a hundred horse power boiler which recently sailed into the air like a sky rocket, paused for an instant, then exploded with a deafening report and a concussion which shook the city like an earthquake, and great pieces of iron flew in all directions. The cause of this phenomenon is said to have been that the fireman of a hoisting engine boiler fired up at a time when the boiler contained an insufficient amount of water.

Ans. No. I simply consider an explosion the natural consequence of "letting go" of the forces locked up in the steam and hot water, when suddenly released from the power of resistance in the generator—being like the "popping" of corn, where the moisture of the kernel is turned into confined steam by heat, until the pressure becomes too great, when an explosion takes place which shatters the grain.

Questions and Answers Relating to Firing.

Ques. How thick should be the body of coal in the furnace ?

Ans. The thickness of fire to be carried depends altogether on the draught. If the draught is strong it should be heavier than when it is weak, and a bituminous (soft) coal fire should be thicker than one of anthracite (hard) coal. For hard coal three to six inches should be the depth, and for soft coal five to eight inches.

Ques. How should the coal be spread ?

Ans. It should be kept spread evenly all over the grate, and not allowed to burn in holes, leaving the bars bare, as the cold air will rush in and chill the heating surface.

Ques. What is the proper way to clean a fire ?

Ans. Take a hoe and push the upper part of the fire back, leaving the clinkers, ashes, etc., on the grate ; then pull the ashes, etc., out with the hoe. To clean the back end of the grate, you pull the good fire forward again, and draw the clinkers and ashes of the back end *over* the fire, and into the ash-pan. Having cleaned it, you must spread the fire evenly all over the grate, and then cover it over with fresh coal, but not too heavily. Care must be taken with anthracite coal, not to let the fire burn too low

before cleaning it, or else you will not have fire enough left to cover the grate, and it will die out.

Ques. Can you add anything else about firing?

Ans. Whatever is done to a fire should be done quickly, and the furnace door be kept open no longer than necessary. No two fires should be cleaned at the same time. A soft coal fire needs breaking up at short intervals, as it has a tendency to amalgamate, or crust over on top; but a hard coal should not be broken up with the bar. All that is necessary to clean it of ashes is to run the slice bar over the grate, and withdraw it without breaking up the fire.

Ques. In case of a fire threatening the destruction of the whole establishment, what is the first thing to be done?

Ans. The fire under the boilers should be drawn, and the safety valves propped open, so that no explosion may take place after the place has been left, this being done for the safety of the engineers, firemen and others.

Ques. How would you fire a locomotive?

Ans. I would distribute the coal—after the fire is well started—evenly in a strip about a foot wide, along the side-sheets and in the corners, being careful that there are no holes along the side-sheets and in the corners. This leaves a strip across the fire-box, from the fire-door to the flue-sheet, that I do not put any coal on.

Ques. How does the coal get into the center?

Ans. I claim that the engine does it. When the coal is put into the fire-box the heat soon drives the gas and other matter out, converting it into coke, and coke being very light the draft will carry it to center of fire-box. The corners and along the sides being a little higher after coal has been put in also aids the draft. The fuel furnished to this strip being coke, it takes very little air to burn it, and the draft drawing the gas from the sides to center of box gives more chance for air and gas to come in contact and burn.

Ques. Has this method been tried or is it a theory?

Ans. It has been tried and it is claimed that a saving of 10 per cent. can be made.

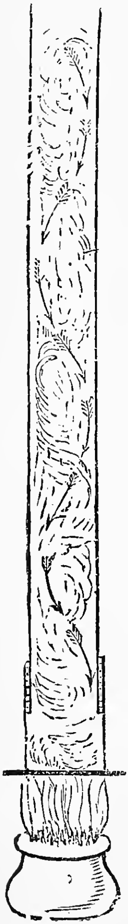
Ques. What should be the first aim in firing?

Ans. To keep an even pressure on the boiler; to adjust the firing to the work demanded of the engine.

Ques. What other general rule would you recommend?

Ans. To handle the fires, the water supply and the management of the steam without sudden changes—allowing always a sufficient time for the different forces to adjust themselves to their changed conditions.

Questions and Answers Relating to the Circulation of Water in a Boiler.



Ques. What is circulation of water in a boiler?

Ans. When a body of water is heated through the shell of a boiler a movement takes place, and the heated particles rise to the top, and the cooler particles from above take their place. These particles of water do not move the same in all parts of the boiler, in some portions the movement will be upward and in other portions downward, and in this way the circulation in a boiler is produced.

Ques. What particular force, or energy, produces this movement?

Ans. Heat. The movement of the water is due to the difference in weight of the particles. The water at the bottom becomes heated and expands in consequence, and thus becoming somewhat lighter than the colder particles, is forced upward by the greater density of the cold water above. In this way, too, heat is diffused throughout the whole body of water in the boiler.

NOTE.—The cut shows the ebullition as it goes on in a restricted space.

Ques. Is there any other force which comes into action to produce the circulation ?

Ans. Yes. The columns of rising steam obtain great physical power, violently and mechanically forcing upwards the water which comes in their way.

Ques. Is it important to provide for these rising globules or columns of steam ?

Ans. The flues and water spaces in boilers should be so arranged as to provide a regular and unrestricted circulation of both the downward and the upward flow of hot water and the upward rush of the steam.

Ques. Where does the movement of the particles begin ?

Ans. At the bottom.

Ques. In what department is the knowledge of the circulation of heated water most needed ?

Ans. In the steam and hot water heating of buildings and work shops, etc.

Questions and Answers Relating to Combustion of Coal.

Ques. What does the word combustion mean?

Ans. To burn, to kindle, to light.

Ques. Before any burning of coal can take place what must occur?

Ans. The coal must suffer the preparatory process of decomposition. It must be dissolved in minute particles of gas or coke. In the combustion of bituminous, or soft coal, there are two distinct operations, viz.: the distilling of the gas and its combustion, and the combustion of the remaining solid carbon or coke.

Ques. What part is first consumed?

Ans. The gas. This unites with the oxygen of the air and burns first.

Ques. What burns next?

Ans. The coke, in the same way as the gas, *i. e.*, the particles of the coke unite with the oxygen of the air and it in turn is consumed.

Ques. How is the gas ignited?

Ans. The heat under which the gas itself distills will always ignite it if the due admixture of air is immediately obtained.

Ques. Is it necessary to have air admitted, and if so, which is the best manner of supplying it to the fuel in order that it may be most effectively consumed?

Ans. Air is absolutely essential and is best admitted through the grate-bars to the furnace in innumerable fine jets, since gas and air mix only gradually. Air in bulk mixes only superficially with gas, and, by abstracting heat, cools the furnace. Gases to be thoroughly burned in the furnace must be intercepted at the start, else the combination, which is at best gradual, will not be completed in season.

Ques. As to air entering the furnace above the burning fuel, is it desirable?

Ans. A proper amount of air (oxygen) entering the furnace above the fuel in small quantities assists somewhat in the combustion of the gases, but a great quantity is detrimental and injurious.

Ques. Is there any other theory about this?

Ans. Yes. It is claimed that if the fuel is not put on the grate in too thick a layer no necessity for such introduction of air is necessary.

Ques. In supplying air to the furnace is it an advantage to have it heated?

Ans. Probably not. There are certain practical objections to heating the air supply for boiler furnaces. First, for every 480 degrees Fahr. of added heat its bulk is enlarged by the amount of its

original volume, so that at 3000 degrees, the heat of the interior of the furnace, it has six times its original volume. It is, consequently, more unmanageable; and as its contained oxygen retains the same weight, its mixture with the gas becomes more difficult, while when mixed it can only do the same work as before. It would be much better to condense the air than to expand it. Next, if heated by passing through flame or over burning coal, the air will be robbed of a greater or less part of its vital oxygen. This is a positive loss.

Table of Heat of Combustion.

Combustible.	Total units of heat of combustion per lb.	Lbs. of water evaporated from and at 212°.
Hydrogen	62,032	64·2
Carbon burned to carbonic oxide	4,400	4·55
Carbon burned to carbonic acid	14,500	15·0
Anthracite	14,700	15·2
Bituminous coal	14,000	14·5
Coke	13,640	14·1
Cannel coal	14,000	14·5
Petroleum	20,360	21 0
Coal gas	20,800	21·5
Oak wood (dried)	7,700	8

Ques. What is the combustion chamber?

Ans. It is that space under the boiler wnere the burning or combustion of the fuel takes place.

Ques. What is the first essential in the construction of the combustion chamber?

Ans. It must be large enough, as the fuel before burning must be enormously expanded. It is said that a lump of coal the size of a man's fist or less, must be expanded so that it occupies a cube measuring nine feet each way—hence the combustion chamber must be very large indeed compared with the space occupied by the solid fuel as it is placed upon the grate bars.

Ques. Give the successive processes of combustion as developed in making a coal fire.

Ans. It is a progressive process. 1, The match, by friction, ignites the phosphorus on its tip, at 150° Fahrenheit; 2, this sets fire to the sulphur at 500°; 3, this causes the soft wood of the match to burn at 800°; 4, which in turn fires the coal at 1,000°; 5, at this point the coal unites with the free oxygen of the air and carries the furnace heat up to 4,000°, more or less, and completes the process.

Ques. What is a combustible?

Ans. Something which burns—coal, oil, wood, are combustibles.

Questions and Answers Relating to the Construction and Strength of Steam Boilers.

Ques. Of what material are boilers built?

Ans. Of sheet steel, as owing to furnace improvements this superior metal can now be made cheaper than wrought iron, and, moreover, mild steel has proved to be the best.

Ques. What is the process of joining the sheets together called?

Ans. Riveting, although in certain cases the sheets have been welded, and in time this may become the general rule.

Ques. What are the two principal kinds of riveting?

Ans. Two—single and double. Single riveting for the girth seams of the boiler and double for the lengthwise seams. In the latter the rivets form a zig-zag line at each joint or seam.

NOTE.—THE AMERICAN BOILER MAKERS standard of strength for steel boiler plate is as follows: "Tensile 55,000 to 65,000 lbs. per square inch of section; elongation in 8 inches 20 per cent. for plates 3/8 inch thick and under; 22 per cent. for plates 3/8 inch to 3/4 inch; 25 per cent. for plates 3/4 inch and under. Specimen piece must bend back on itself (cold) without fracture; for plates over 1/2 inch thick specimen must withstand bending 180° (1/2 way) round a mandril 1½ times the thickness of the plate. Chemical requirements: phosphorus not over .040 per cent.; sulphur not over .030 per cent."

Ques. What size rivets are used in joining the sheets?

Ans. They are long enough to bend over and form a head, and of a diameter suited to the different thickness of the plates, ⅝, ¾, ⅞, according to the specifications for making a boiler when it is first constructed.

Ques. What is the thinnest sheet which should be used in a boiler?

Ans. One-quarter of an inch; this is the thinnest which can be caulked to advantage.

Ques. What is caulking?

Ans. This is the closing of the seams after the riveting has been done, and is executed by a blunt chisel; when the work is done by a round nosed chisel it is called "fullering."

Ques. Is a thin plate better than a thick one?

Ans. It is said by practical boiler makers that the thinner the sheet—so long as it affords sufficient strength—the longer it will last under the varying strains to which a steam boiler is subjected, and that the caulking will also last longer and better.

Ques. What are the flanges of a boiler?

Ans. They are those parts which are bent over; this is called flanging; for example, the heads of the tubular boiler are turned over to be joined to the shell, or body sheets.

Ques. What are the "lugs" of a boiler?

Ans. The lugs are the castings riveted on each side of the boiler which support or "lug" it. There are commonly three or four lugs on each side.

Ques. Suppose the water should fall below the lowest gauge-cock, what is to be done?

Ans. If the fires are light, they should at once be hauled; but should they be heavy, the better plan is to smother the fire with fresh coal, dust, or ashes out of the ash-pans.

Ques. What are the two principal methods of testing steam boilers?

Ans. There are two methods in general use, known as the "hydrostatic test" and "hammer test." The former test consists in filling the boiler with water, and then with a hand force-pump raising the pressure up to that which it is supposed the boiler will stand. The "hammer test" is applied in all accessible parts of the boiler, such as the shell flues, and braces, by tapping with a light hammer.

Ques. What is meant by the pitch line of riveted work?

Ans. The distance from center to center of the rivet.

Ques. How far from the edge of a sheet may a rivet hole be properly made?

Ans. A distance equal to the diameter of the rivet hole, *i. e.*, the space between the edge of the

rivet hole and the edge of the sheet must equal the diameter of the rivet.

Ques. Does the removal, or punching out, of the metal for the rivet hole weaken the plates and consequently the boiler?

Ans. Yes.

Ques. What is the rule as to pitch of the rivets in view of this weakening?

Ans. There shall be the same strength of iron between the rivets as there is in the rivets themselves.

Ques. What is the most advantageous thickness of boiler plates?

Ans. It has been found by experience that a thickness of about ⅜ of an inch is the most favorable to sound riveting and caulking of boiler plates; and they are seldom made much thicker or thinner than that thickness; if more strength is needed in a boiler it is better to reduce the diameter of the shell than to increase the thickness of the plates.

Ques. Is it usual to make the heads thicker than the shell?

Ans. Yes. Where the shell is ⅜ the ends are made ½ inch, and in that proportion.

Ques. What is the name of the round plate which forms the ends of a tubular boiler?

Ans. The tube plate, because in it the ends of the tubes are riveted and beaded.

Ques. How many principal kinds of seams are there in boilers ?

Ans. The "lap" and the "butt" joint, the names of which signify the way in which the sheets are riveted.

Ques. How do you ascertain the strength of a riveted seam ?

Ans. It is customary to multiply the tensile strength of the metal by .70 or $\frac{7}{10}$ for double riveted longitudinal seams and .56 for single riveted.

Ques. Give an example.

Ans. If the steel plates have 60,000 lbs. tensile strength per square inch, then ⅜ of the square inch would be 22,500 lbs.—multiplying this by .70 gives 15,750 pounds as the strength of the double riveted seam.

Or multiplying by .56 it gives 12,600 as the strength of the single riveted seam.

Ques. How does the strength of a seam compare to that of a solid sheet ?

Ans. The custom is roughly to consider the strength of the single riveted seam to be one-half that of the solid sheet and the double riveted three-fourths.

Ques. When inspectors figure the allowable pressure upon a boiler how do they proceed ?

Ans. They take the strength of the seam and the strength of the weakest plate. They also figure the size and pitch of the rivet.

Ques. Can you give a short rule for determining the strength of a boiler—taking the weakest sheet ?

Ans. Multiply the thickness of the weakest plate in the boiler by its tensile strength per square inch in pounds, and divide the product by one-half of the diameter of the boiler in inches, and multiply the product by .56 for single riveted longitudinal seams and by .70 for double riveted longitudinal seams.

Ques. What will be the strength of a boiler with ¼ inch plates of 50,000 lbs. tensile strength, double riveted, and boiler 40 inches in diameter ?

Ans. One quarter plate gives ¼ of the strength of the square inch of section = 12,500 ; divide this by ½ (of 40 in. diam.) 20 = 625 lbs. This would be for a solid sheet; for double riveted multiply by $\frac{7}{10}$ = 437$\frac{50}{100}$ lbs. total strength.

Ques. Would inspectors allow this as the pressure to be carried ?

Ans. No, for they have, by law and custom, "a factor of safety," which only allows one-fourth to one-sixth.

Ques. With a factor of six, how much will be allowed in this case ?

Ans. About 75 lbs

Ques. With a factor of five, how much?

Ans. About 85 lbs.—the figure being approximated by the inspector—if needed.

Ques. What have you to say as to grate bars?

Ans. When the furnace is more than four (4) feet long the bars should be put in in two lengths, but if it is four feet or less in length, one bar will suffice, in which case only two bearing bars will be required. When a center bearing bar is used for two lengths, it should be made like a double grate-bar—that is, with an opening or air-space in the middle. Grate-bars when hot expand considerably, and therefore they should not be put in tight, or too close together, but should have end and side play, otherwise they will bend and twist out of shape and soon be destroyed.

Ques. Does heating a boiler in the regular "firing" weaken or strengthen it?

Ans. It strengthens it, because wrought iron heated to a point less than 600° Fahr. increases in strength, and as at 200 lbs. pressure on the boiler per square inch the temperature is less than 400°, it follows that it grows stronger.*

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*NOTE.—Under a test it has been shown that the strength of iron increases up to 570°, when it begins to decrease with the added heat.

At	32°	it	was	56,000	lbs.	per	square	inch.
"	570°	"	"	66,500	"	"	"	"
"	720°	"	"	55,000	"	"	"	"
"	1050°	"	"	32,000	"	"	"	"
"	1240°	"	"	22,000	"	"	"	"
"	1317°	"	"	9,000	"	"	"	"

Questions and Answers Relating to the Physical Properties of Steam.

Ques. What is steam?

Ans. Steam is an invisible elastic fluid, or water, brought to the state of gas by the application of heat.

Ques. What is live steam?

Ans. Live steam is steam under pressure and ready to do work through the agency of the steam cylinder, or for heating, boiling, etc.

Ques. What is dead steam?

Ans. Dead steam is the opposite of live steam —such as exhaust steam or the vapor which fills the steam generator before there is any pressure.

Ques. What is dry steam?

Ans. Dry steam is that which holds no water in suspension. High pressure steam has been proved by experiment to be dry like dust.

Ques. Why is steam invisible except as it is being condensed?

Ans. Like many other gases it possesses the quality of invisibility.

Ques. What is saturated steam?

Ans. This is steam under pressure in contact with water in the boiler; its condensing point agrees with the boiling point of the water on which it rests

Ques. What are the constituents of which steam is formed ?

Ans. It contains the same elements as the water of which it is formed, *i. e.*, two gases, oxygen and hydrogen.

Ques. In what proportions do these exist in water and steam ?

Ans. Two volumes of oxygen and one volume of hydrogen, but in weight the hydrogen is the lightest.

Ques. Are the oxygen and hydrogen (gases) found in coal the same substances as those described in above answer ?

Ans. Yes, because these two are simple bodies in themselves, while found in thousands of combinations with other original elements.

Ques. If water is confined in a boiler, and the vessel entirely full, and then heated to a high temperature, will there be any steam formed.

Ans. No, because steam requires space in which to expand.

Ques. How many times is water expanded in being changed into steam at the pressure of the atmosphere ?

Ans. Into sixteen hundred and sixty-nine times the volume ; or roughly, 1,700 times.

Ques. What occurs in the expansion when a pressure is placed upon the boiler ?

Ans. It expands according to the pressure. The greater the pressure the less the volume. This is given in tables carefully computed; at a pressure of 150 lbs. to the square-inch the volume is reduced to 284 times, and at 300 lbs. pressure to 96 times.

Ques. What is superheated steam?

Ans. When steam is separated from the water over which it was formed, and afterwards re-heated to a higher temperature than the water and steam it becomes superheated steam.

Ques. Which is the heaviest, a pound of steam or a pound of water?

Ans. A pound of steam is the same in weight as a pound of water. It is good form to say that the engine uses "so many pounds of steam" instead of so many pounds of water.

Ques. Which is the heaviest at atmospheric pressure, steam or air?

Ans. Steam is the lightest, because it always rises. It is about two-thirds the weight of air. In the tables it is put down at .625.

Ques. When air is confined with steam inside the boiler. which is then the heaviest?

Ans. Both being under more than atmospheric pressure (14 lbs. to the inch), air will be the lightest because its rate or ratio of compression is greater. *i. e.*, steam compresses more readily than air.

Ques. Is air confined in the boiler with steam considered hurtful or dangerous ?

Ans. No, as with the immense volume of steam being formed and used through the engine it soon passes off. Some engines are altogether operated by compressed air.

Ques. What is wet steam ?

Ans. Steam full of spray—or with water mechanically suspended in the steam.

Ques. What is the difference between high and low pressure steam ?

Ans. High pressure steam is commonly understood to mean steam used in high pressure engines, and low pressure steam is that used at low pressure in condensing engines, heating apparatus, etc., at 15 lbs. pressure or under.

Ques. At what temperature does water evaporate ?

Ans. Water evaporates at all temperatures above freezing point, and boils at 212°.

Ques. What is absolute pressure of steam ?

Ans. Absolute pressure is its pressure estimated or reckoned above vacuum ; or the steam pressure shown by the ordinary steam gauge with the pressure of the atmosphere added ?

Ques. What is initial pressure ?

Ans. Initial pressure is that in the cylinder of an engine at the beginning of the forward stroke of the piston.

Ques. What is terminal pressure ?

Ans. Terminal pressure is that which would be in the cylinder at the end of the stroke of the piston if the exhaust valve did not open until the stroke was finished ?

Ques. What is wire drawing ?

Ans. Wire drawing is the operation of reducing the pressure of steam between the boiler and the cylinder ?

Ques. Does the change from water to steam, by the application of heat, affect the relation of the particles of the different fluids ?

Ans. As water, the particles are strongly cohesive, but as steam the particles are repellent. It is this repellant force existing among the infinitely small atoms of steam which appears to give the energy to the mass of steam and renders it serviceable.

Ques. Does this change mean anything looked at as power ?

Ans. The fluid, as water, is inexpansive, but the change to steam gives it energy or the ability to do work by the reason of its great expansive or elastic tendency.

Ques. Has the process we call boiling anything to do with steam ?

Ans. Yes. Boiling is caused by the formation of steam particles.

THE STEAM ENGINE.

While machines may vary greatly in different particulars, the laws of matter are the same, and will remain unchanged for all time ; hence it must be borne in mind that success in the design, care and management of an engine, no matter what may be its size, kind or use, can only be achieved by a close observance of the fundamental laws which govern the formation and use of steam.

All steam engines may be divided into two great classes, according as they are or are not provided with apparatus for condensing the steam. These classes are: 1, condensing, or low pressure engines; 2, non-condensing, or high pressure engines.

Engines of the second class are on the whole less economical of fuel than those of the first class, but, having fewer parts and occupying less space, they are much used where simplicity and compactness are considered of more importance than economy of fuel.

A second mode of classing steam engines is founded on the way in which steam acts on the piston, and is as follows:

1. Single acting engines, in which the steam performs its work by its action on one side of the piston only.

2. Double acting engines, in which the steam exerts energy on either side of the piston alternately.

3. Rotatory engines, in which the steam drives a revolving piston round.

A third mode of classification distinguishes engines into—

1. Non-rotative, in which no continuous rotation is produced, as in single acting pumping engines, steam hammers, etc.

2. Rotative engines, in which the motion is finally communicated to a continuously rotating shaft.

Rotative engines are now the most common. Non-rotative engines are exceptional.

A fourth mode of classing engines is founded on their purposes, as follows:

1. Stationary engines, such as those used for pumping water, for driving manufactory machinery, etc.

2. Portable engines, which can be moved from place to place but are stationary when at work.

3. Marine engines, for propelling vessels.

4. Locomotive engines, for propelling vehicles on land.

Stationary engines exist of all the classes belonging to the three previous modes of classification. Portable engines are usually non-condensing, to save space, and to adapt them to situations where injection water cannot be obtained in sufficient quantity. Most of them are also double acting and rotative. Marine engines are in general condensing, double acting and rotative. Locomotive engines are almost all non-condensing, and are all double acting and rotative.

In the selection of an engine there are six points to observe relating to it before its purchase:

I. Its simplicity.

II. Its strength.

III. Durability and least wear.

IV. Economy in the use of steam.

V. Regularity of speed.

VI. Fitness for its work.

Any intelligent engineer has observed that his engine has an individuality not possessed by any other, and a personal acquaintance with its peculiarity is quite necessary to obtain the best results from it. This remark applies with equal or greater force to the steam boiler and steam pump, and the successful engineer or fireman is the one quickest to understand "the points" of his machine.

Great progress has been made in the art of engine building since the introduction of electric light and power plants and every indication is that still greater perfection will be gained.*

*NOTE.—In marine engineering the progress in coal economy has been wonderful as may be seen from the following table:—

Year.	Pressure of steam by boiler gauge per sq. in.	Consumption of coal per I. H. P per hour.
1330	2 to 3 lbs.	9.0 lbs.
1840	8 "	5.5 "
1850	14 "	4.0 "
1860	30 "	3.0 "
1870	40 to 40 "	2.6 "
1880	70 to 80 "	2.2 "
1886	150 to 160 "	1.5 "
1889	175 "	1.4 "
1890	200 "	1.4 "

Questions and Answers Relating to the Steam Engine.

Ques. Along what lines has the latest development of steam engines been carried?

Ans. There is a steady progress in the production of stronger, more rigid engines, using higher steam pressure and to run at higher speeds than now. The automatic cut-off is rapidly displacing the old throttling engine, and much attention is paid to condensers and the compounding of steam.

Ques. What cause has operated to produce the necessity for stronger and more rigid engines and larger bearing surface?

Ans. The higher speeds—100 revolutions per minute being now not uncommon. A speed of 160 revolutions per minute or 1120 ft. piston speed has been recorded in a 20x42 in. Corliss engine.

Ques. Which engine holds first rank as the most economical and generally satisfactory type?

Ans. The Corliss.

Ques. In what cases has the compounding in the Corliss engine been found advantageous?

Ans. Where large power is demanded. In smaller powers the ordinary simple expansion engine has been found sufficiently advantageous.

Ques. What are the two great classes into which engines are divided?

Ans. Throttling and automatic.

Ques. Where is the difference?

Ans. In the principle of regulation in supplying the steam from the boiler to the engine by automatic or throttling valves.

Ques. Which is the oldest system?

Ans. The throttling principle was almost universal until Corliss introduced his automatic cut-off engine, which he made an immediate success by guaranteeing certain results from the use of a specified amount of fuel.

Ques. What is the advantage of the automatic cut-off as claimed by engine builders?

Ans. It comes from the fact that most steam engines are subjected to variable loads, and quite generally some difference in steam pressure. The economical point of cut-off varies with the load, and the automatic cut-off governor so varies the amount of steam as to secure the best results, pressure being constant

Ques. In what places are the throttling valve engines without objection?

Ans. Where there are but little variations, either in the pressure of steam or in the duty to be performed.

Ques. What can be said about simplicity in an engine?

Ans. It is always a point of great importance to build an engine containing the least number of parts and the simplest elements attainable in construction and design, such as the form of frame or bed, piston head, packing rings, cross-head, guides, connecting rod ends, valve gear, valves and regulating appliances.

Ques. What about the strength of an engine?

Ans. All parts should be so proportioned as to insure the greatest durability and to prevent tremors and strains.

Ques. What about the point of durability?

Ans. The least variation in the line of the engine, a slight settlement of the foundation, unequal wear of a bearing or failure of oil to flow but for a moment, will cause parts to heat, wear and ultimately fracture ; hence the new engine should be speeded only as fast as will enable the mechanism to continue its work with the least wear and stress, thus avoiding the error (now exposed) that the rate of speed of a perfectly constructed engine is unlimited.

Ques. What can you say about economy in the use of steam?

Ans. This is an element of vital importance and relates to the distribution of the steam in the cylinder. It embraces the least amount of clearance or dead space consistent with the smooth running

of the engine, prevention of the loss of heat from the steam in the cylinder, an initial steam pressure in the cylinder equal to the boiler pressure; a minimum back pressure; rapid action of the admitting and cutting off edges of the valve; a proper amount of cushioning; and last but not least, a fitness of the engine for its work, in size and the character of the valve gear.

Ques. Is regularity of speed in an engine of importance?

Ans. One of the most essential features of a good engine is regularity of speed under varying loads. A high attainment in this respect is a variation of only 3 per cent. in two revolutions.

Ques. What have you to say about the fitness of an engine for its proper work?

Ans. It is of the utmost importance to choose an engine of the proper size and character to suit the work it is intended for. It is folly to purchase a fixed cut-off engine for greatly varying loads; it is also poor economy to apply to a small steady load an expensive automatic cut-off engine, or one so large that the ratio of expansion becomes excessive and exceeds the limit of economy. Each steam plant requires its special engine to be of the proper proportion.

Ques. What is "clearance"?

Ans. Clearance in a cylinder is the space allowed for the piston to clear the cylinder heads at the end or beginning of a stroke.

Clearance is also a term used to include also the volume of the ports. It is evident that this space, as well as the space through which the piston sweeps, has to be filled with steam.

Ques. What is "lead"?

Ans. Lead is the amount of the opening of the steam port at the beginning of the stroke of the piston, sometimes called pre-admission.

Ques. How would you give a valve its lead?

Ans. Place the eccentric sheave ahead of its true position.

Ques. To cut the steam off at a given part of the stroke how would you alter the valve?

Ans. By making the width of the face of the valve larger or smaller, as the case demanded.

Ques. What would you call this then?

Ans. Lap or cover.

Ques. What is the "lap" of a valve?

Ans. The "lap" is that part of a valve which is more than necessary to cover the steam ports when the valve is in mid-position.

Ques. Is there any lap on the exhaust valve? What is it?

Ans. There is exhaust lap and it is how much the edge of the exhaust valve is over on the cylinder bar beyond the exhaust edge of the port when the valve is in mid-position.

Ques. Why do we have lap on the exhaust edge?

Ans. To get larger cushion.

Ques. What kinds of engines call for this?

Ans. Those of great size and weight having short and very quick travel.

Ques. Why is "lap" given a valve at all?

Ans. To close the port before the piston reaches the end of the stroke, and thus make the steam work bv its expansion.

Ques. What is the difference between fixed and movable expansion?

Ans. The first is expansion by the lap of the valve, and the second is expansion by separate gearing or valves.

Ques. What other name is given the expansion valve for cut-off?

Ans. The "link."

Ques. Does the piston stop at any point of the stroke?

Ans. Yes; when passing the centre.

Ques. What is the operation of the slide valve?

Ans. To allow the steam to flow alternately first at one end and then to the other of the cylinder and open the opposite port alternately to the exhaust

Ques. What is the object of a crank?

Ans. To convert a straight line motion into a circular one.

Ques. Describe the duties of a slide valve with reference to the positions of the piston?

Ans. Steam is flowing into the cylinder and pushing the piston, then when the piston has travelied one-fourth or one-half or any part of the stroke before determined on, the valve must close the steam port to cause expansion ; it must again open this port to the exhaust just before the piston arrives at the end of the stroke so as to have a vacuum to commence the return stroke with ; it must close the exhaust a little before the piston arrives at the other end to cause cushioning and just before the end of the stroke, it must open this port to steam to commence the new stroke.

Ques. What do we mean by a "vacuum"?

Ans. Any space void of all pressure.

Ques. Is an absolute "vacuum" obtainable?

Ans. No.

Ques. Does the condenser have anything near a perfect vacuum?

Ans. Yes, quite near ; but there is always a small pressure there.

Ques. To show 11 lbs. what must the vacuum gauge read?

Ans. 22 inches.

Ques. What does 11 lbs. vacuum mean to a steam engineer?

Ans. It means that he can work his steam down to 4 lbs. before it exhausts, as the condenser has destroyed 11 of the 15lbs. atmospheric pressure at which the steam would usually exhaust.

Ques. What is implied by the term "back pressure"?

Ans. As perfect vacuum is impossible, a certain vapor retards the piston equal to the distance between a perfect vacuum and what the gauge reads.

Ques. What is the difference between a high and low pressure engine?

Ans. The first exhausts into the air, having no condenser, while the second exhausts into a condenser, thus saving the pressure against the atmosphere.

Ques. What is a compound engine?

Ans. An engine built to get the same expansion not of the steam as does a simple engine, but by means of later cut-off.

Ques. How do they contrive to do this?

Ans. By using, in addition to the usual high pressure cylinder, a large second cylinder, where the steam has additional room for expansion before escaping into the condenser.

Ques. Does water ever get into the cylinder, and what happens when it does?

Ans. Sometimes water gets in through priming and is apt to split the piston or blow off the cover of the cylinder.

Ques. Can you get rid of this water?

Ans. Yes, by the escape valves.

Ques. How can you reverse the motion of a slide valve engine?

Ans. 1st, place the engine on the dead centre, noting the amount of lead on the valve. 2d, slack up the set screw of the eccentric and turn it ahead (same way it has been running) on the shaft until the valve has moved to the extreme of its travel. 3d, move it back until it has the same lead as before, and tighten the set screw.

Ques. In putting in a new shaft, how would you adjust the eccentric?

Ans. Put the crank on its top center with the valve at its proper lead at the top. Next fasten the sheave with set bolts to keep the valve lead secure; when all is connected, then, after a turn of the engine, see if the valve has the proper lead at the bottom when the crank is on the bottom centre. If such is the case, mark the key ways, and key on the sheave.

Ques. What is the cylinder?

Ans. The cylinder consists of a cast iron true bored chamber and a steam chest or valve box.

Ques. What are the openings from the steam chest to the cylinder called?

Ans. Steam ports.

Ques. Which are the exhaust ports?

Ans. Those which open from the cylinder to the air.

Ques. What is the "stuffing-box"?

Ans. The "stuffing box" is that part of the cover through which the piston passes. It is rendered steam-tight by a filling or packing of tallowed hemp, etc.

Ques. What is the "gland"?

Ans. This is the cover which presses down the packing against the rod, and is secured by two screwed bolts.

Ques. What is cylinder condensation?

Ans. It is that portion of the steam which condenses and is deposited on the metallic surface of the cylinder when the cylinder is colder than the steam entering it.

Ques. Does this moisture remain in the cylinder?

Ans. No. It evaporates on the opening of the exhaust, thereby cooling the walls of the cylinder again.

Ques. What is the result of all this?

Ans. The steam is lost and a back pressure generated thereby.

Ques. Is this loss very great?

Ans. Yes, sometimes being as much as 50% of the whole steam consumed.

Ques. How can this loss be partly remedied?

Ans. 1. By "jacketing" the cylinder with hot steam. 2. By "cushioning" or detaining and compressing (thus raising the temperature) a part of the exhaust steam, using the heat thus generated to keep the cylinder hot. 3. Compounding the cylinders.

Ques. How would you test for a leaky slide valve?

Ans. Block the fly-wheel when the slide valve is in the middle of its stroke and open the indicator taps, or the relief cocks, or look at the exhaust pipe. A steady escape of steam indicates a leaky valve.

Ques. How would you test for a leaky piston?

Ans. Block the fly-wheel when the piston is situated at a short distance beyond the beginning of the stroke. Admit steam to the piston and open the indicator tap, or relief cock, on the exhaust side of the piston. An escape of steam will indicate a leaky piston. The leak may be caused by a leaky slide valve, so this should be tested first.

Ques. Should engines stand idle for any length of time, what should be done?

Ans. They should be turned partly round each day.

Ques. What should be done before starting an engine?

Ans. The stop valve should be opened a little, before the fire is lighted, so that, while the steam is being generated in the boiler, it may pass through the cylinders and jackets and warm them gradually, the temperature rising as the pressure rises. Meanwhile all drain cocks from the slide jackets and cylinders should be opened to allow the steam to flow through, and the condensed steam to pass away. This will prevent the possibility of the cylinder cracking owing to sudden admission of hot steam against the cold metallic walls of the cylinder. This is especially important in cold weather.

Ques. How would you manage the drain cocks?

Ans. The drain cocks should remain open for a few revolutions till all water has been blown out of the cylinder, and then closed.

Ques. How about the oil?

Ans. I would see that all the lubricators were in good condition, the holes clear, and the worsteds clean, and that the lubricators were well supplied with oil.

Ques. If a low pressure or condensing engine, how would you proceed?

Ans. If a condensing engine, the vacuum gauge should be watched; and, if the vacuum is not maintained, the injection, or circulating water, should be

regulated. If this does not produce the desired effect, there is probably an air leak through the piston-rod gland, or the air-pump-rod gland, which should be screwed up; and, if the vacuum is still defective, the cause must be looked for in the foot and head valves or the air-pump bucket valve (if any), or in leaky condenser tubes.

Ques. How is the horse power of steam engines determined?

Ans. By the following rule: Multiply the area of the piston in square inches by the average force of the steam in pounds and by the velocity of the piston in feet per minute; divide the product by 33,000, and $\frac{7}{10}$ of the quotient equal the effective power.

Ques. How is the "average force" of the steam in the cylinder, or, as it otherwise is expressed, the "mean effective pressure", found?

Ans. The mean effective pressure can be accurately determined only by the aid of an indicator.

Ques. Without the aid of an indicator how do you proceed?

Ans. When the indicator is not used in the calculation the boiler pressure is substituted for the mean effective pressure. Deduct from the result obtained from 40 to 60 per cent. for loss by condensation and friction of steam pipes and passages

decrease of pressure in cylinder due to expansion, back pressure of exhaust and friction of the working parts.*

Ques. How do you proceed with a compound engine?

Ans. By the same rule applied to each cylinder—adding the totals together gives the power of the whole.

Ques. What are compound engines?

Ans. Compound engines are those which have two or more cylinders of successively increasing diameters so arranged that the exhaust steam from the first and smallest cylinder is passed forward to do work in a second cylinder before escaping to the condenser.

Ques. What are the particular advantages claimed by compounding?

Ans. 1, The compound engine enables the fullest advantage to be taken of the expansive power of very high-pressure steam; 2, The ease with which it may be adapted to work on one or more cranks, thereby reducing the excessive variation of strain which occurs in a single cylindered engine using high pressure steam.

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*Note.—The mean pressure in the cylinder when cutting off at

¼	stroke	equals	boiler	pressure	multiplied	by	.597
⅓	"	"	"	"	"	"	.670
⅜	"	"	"	"	"	"	.743
½	"	"	"	"	"	"	.847
⅝	"	"	"	"	"	"	.919
⅔	"	"	"	"	"	"	.937
¾	"	"	"	"	"	"	.966
⅞	"	"	"	"	"	"	.992

Ques. How may compound engines be classified?

Ans. Into those, 1, where the piston of each cylinder commences the stroke at the same time; 2, and those which exhaust from one cylinder before the next cylinder is ready to receive it; in which case the steam is retained, for a portion of the stroke, in a chamber or receiver between the two cylinders. These are termed "receiver" engines.

Ques. What is to be said about triple and quadruple expansion engines?

Ans. The principles which govern the construction and management of the compound are the same in the triple and quadruple expansion engines, namely, those in which the steam is expanded in three or four cylinders respectivelv. These are the necessary outcome of increased pressures of steam; for, since the terminal pressure is about constant, increased pressures involve an increased number of expansions. And in order to prevent undue range of stress and temperature, three and even four cylinders are now employed.*

* Thus the same reasons which led to the rejection of the single-cylinder engine in favor of the two-cylinder compound, have now led to the rejection of the two-cylinder engine (at least, in marine work), and the adoption of the triple-compound, and in some cases the quadruple compound in its stead. The steamer "Northwest"—Buffalo to Duluth—has engines of the quadruple cylinder type and are worked at 200 lbs. steam pressure, the cylinders being 25″, 36″, 51½″, 74″ by 42″ piston stroke, 120 revolutions, developing with ease 7,000 H. P. The screws (twin) are 13 feet diameter, 18 feet pitch, assuring speed of over 20 miles per hour.

ENGINE AND BOILER FITTINGS.

In the efficient operation of a steam plant, next to a well set boiler or boilers with a good draught, there comes an economical, strong and suitably proportioned engine—one or more.

BUT, not less an importance and real necessity there must be the connections, fittings and appliances, in the selection of which equal care and good judgment must be brought into play.

In the choice and arrangement of these fixtures the first thing to be observed is that they shall be of the very best of their kind as far as may be possible. 2d, each appliance should be in fair proportion to the other parts of the plant—neither too large nor too small, and 3d, they should be well and thoroughly "fitted"—the skill of a good engineer is shown in this as much as in setting a main valve or putting a "spectacle piece" on a boiler. 4th, every appliance should be kept in the best of working order and in the neatest condition with foresight also as to their giving away at an unexpected moment.

The latter consideration implies the keeping on hand, as far as practical, of duplicates of all fittings and appliances, both in the engine and boiler rooms. Especially is this well where "the plant" is not in the vicinity of shops and supply houses.

Questions and Answers relating to Engine and Boiler Fixtures.

Ques. What are the principal belongings that are usually considered fixtures of a steam boiler ?

Ans. The safety valve ; globe and check valves ; steam gauge ; the front, containing tube, fire and ash pit doors ; grate bars, with bearing bars ; dead plates ; man and hand hole plates and thimbles ; water gauge cocks and glass gauges ; blow-out apparatus ; fusible plug ; surface blow cocks with scum apparatus ; steam whistle ; and for the brick work, binder bars, anchor bolts, back stays, cleaning out doors, and lugs to support the boiler.

Ques. What other appliances can you name necessary to complete the operation of a steam boiler ?

Ans. The pump or injector ; the feed water apparatus with piping of various kinds ; the steam pipe (with globe valve) leading to the engine ; feed water heater ; steam-trap ; the chimney and damper; the fire-tools, flue brushes and scaling tools, with the hose to wash out the boilers ; water meters ; strainers and foot-valves for clearing the water before entering the boiler.

Ques. What are thimbles in use on boilers ?

Ans. These are the heavy castings riveted on the upper shell of the boiler with flanges planed to which to bolt the safety valves or pipe connections —a thimble in gas pipe definitions is "a connection."

Ques. What is a globe valve?

Ans. A globe valve takes its name from its shape. It is a valve in a round chamber.

Ques. How should globe valves be attached?

Ans. So that the pressure comes under the valve, or at the side, for if the valve should become loose from the steam (which they often do) if the pressure is on top, there would be a total stoppage of the steam.

Ques. What is a valve?

Ans. A valve has a seat and is generally turned by a circular handle fitted to the spindle—the best example of a valve is that of an ordinary house pump, where the valve opens upward to admit the water and closes downward to prevent its return.

Ques. What is a cock?

Ans. A cock is a valve but a valve is not a cock —the cock is a cone-shaped valve slotted and fitted with a handle—example: the try-cocks of a boiler are cocks with their openings in line with the blow-off pipes.

Ques. What is a relief valve?

Ans. It is a valve so arranged that it opens outward when a dangerous pressure or shock occurs.

Ques. What is a back pressure valve?

Ans. These are ball (or clack) valves in a pipe which instantly assume the seat when a back pressure occurs. Their name signifies their use—to maintain a constant back pressure in heating systems.

Ques. What is a three-way cock?

Ans. It is one having three positions in which to direct the fluid in three ways. There is also a three-way valve.

Ques. What is a check valve?

Ans. A valve placed between the feed pipe and the boiler to prevent the return of the water, and similar uses.

Ques. What is a ball valve?

Ans. It is a valve occupying a hollow seat. These valves are raised by the passage of a fluid and closed by their own weight.

Ques. What is the throttle valve?

Ans. This is the valve used to admit steam to the engine and so used (in stationary service) to distinguish it from the main stop valve located near the boiler—to throttle means to choke—hence the throttling of the steam.

Ques. What is a reducing valve?

Ans. This is a pressure-regulating valve and designed to reduce the pressure from a high point

in the boiler to a low one in a system of steam heating.

Ques. How should steam valves be connected?

Ans. So that the valve closes, against the constant steam pressure.

Ques. What will prevent cracking and pounding noises in steam pipes in steam heating?

Ans. A thorough drainage of the pipes.

Ques. In steam and cast iron pipe how is the diameter given in the tables?

Ans. By the internal diameter.

Ques. And the diameter of boiler tubes?

Ans. By the external diameter

Ques. How is the strength of steam pipes, elbows, tees, threads, etc., calculated for the safe working pressure?

Ans. By the same rules that are used in figuring the strength, strains, etc., of the steam boiler.

Ques. What factor of safety would be best in view of the small diameter of the pipes?

Ans. A tensile strength of 50,000 lbs. to the square inch may be assumed with safety with a factor of 4.

Ques. What would you do with rusted spots?

Ans. Regarding rusted spots or places where corrosion has taken place, the thickness of good

iron remaining should be taken as the thickness of the pipe or fitting, although small places having an area of 1 square inch or less may be ignored so long as the original thickness of the material remains; but where the corroded area exceeds this, full allowancs must be made. A number of small places corroded, pitted or grooved and closely connected, require that only the thickness of good iron remaining shall be considered as the thickness of the material.

Ques. What is the tensile strength of cast and malleable iron—of which connections are mostly made?

Ans. The mean tensile strength of cast iron is from 16,000 to 20,000 lbs. and a factor of safety of 4 should be employed. The mean tensile strength of malleable iron ranges from 30,000 to 40,000 lbs., and unless tests are made to determine the strength it is better to assume the smaller number, allowing as before a factor of safety of 4.

Ques. What is to be stated about the pipe threads?

Ans. The threaded portions of pipes and fittings, when the greater portion of the thread is entered and the joint made in a workman like manner, will have sufficient strength to withstand the strain on the same principle that the single riveted girth seams have sufficient strength to withstand the strain, even though the longitudinal seams of the boiler be double riveted.

Ques. In taking charge of a new steam plant what is the first thing an engineer should do ?

Ans. Make himself familiar with the water and steam pipes and office of the valves connected with such pipes.

Ques. What are the dead centres or dead points of an engine ?

Ans. At two instants in each revolution, the direction of the crank coincides with the line of connection (or straight line joining the centre of the joints of the connecting rods.) The positions of the crank pins at those instants are called dead points, and they correspond to the ends of the stroke of the pistons when its velocity vanishes.

Ques. What means are provided to overcome the effects of these dead points without jar or irregularity ?

Ans. It is to diminish the irregular action caused by the existence of these dead points and also to facilitate the starting of engines when the crank happens to rest upon one of them that engines are combined by pairs or threes.

Ques. What other device is used to prevent in stationary engines the fluctuations in speed caused by the dead centres ?

Ans. The fly wheel.

Ques. Why are they not used in marine and locomotive engines ?

Ans. In marine service the propeller, whether paddle or screw, answers the purpose of a fly wheel; in locomotives the entire engine suffices to prevent excessive fluctuations.

Questions and Answers Relating to the Safety Valve.

Ques. What is a safety valve?

Ans. It is a bonnet or conical valve loaded with a weight equal to the greatest extra pressure likely to be exerted by the steam on the boiler.

Ques. What is the particular office of the safety valve?

Ans. To relieve the boiler from a pressure which may become dangerous and cause an explosion.

Ques. Is the sound of steam from a safety valve a sign of danger?

Ans. No, it is a token of safety; it shows the valve to be in operation, and if properly set, a sure protection.

Ques. What danger exists when a safety valve "sticks"?

Ans. The valve holds the pressure until it gets higher and higher, until so very high that the safety valve finally gives way and allows so much steam to escape at once that it changes the condition or balance of the steam and water inside the boiler, causing danger of an explosion.

Ques. How should this be guarded against?

Ans. By raising the valve, when under pressure, once or twice a day—doing so very gently and gradually—to make sure that it is in working order.

Ques. When a safety valve is described as a 2 inch valve or a 2½ inch valve, what is indicated by the description?

Ans. It means that 2 inches, or 2½ inches is the diameter of the pipe.

Ques. What part of the boiler is preferable for the position of the safety valve?

Ans. It is best placed upon the boiler at the part furthest away from the water line, so as to be unaffected by the foaming of the water—if any exists.

Ques. Is there more than one variety of the safety valve?

Ans. Yes. The Lever, or the common form, and the Spring loaded safety valve; also the dead-weight safety valve.

Ques. What is the "pop" safety valve?

Ans. It is a well-known form of spring valve and takes its name from the fact that it takes a little more pressure to raise it off its seat than what it is set at, consequently it releases itself with a "pop"

Ques. What are the points of contact of a valve called?

Ans. The fixed part is called the seat of the valve and the part resting upon it is called the face of the valve. The seat is preferably adjusted at an angle of 45 degrees and the face made to fit.

Ques. What is the valve spindle?

Ans. It is the small guiding rod which moves upwards and downwards with the face of the valve. Its office is to keep the two faces opposite and cause the rise and fall to be perfectly even and true.

Ques. What are the most essential problems to be performed in reference to the steam plant, and why?

Ans. Those relating to the safety valve; because the safety valve is the most important fixture belonging to the steam boiler.

Ques. Why should the size of the safety valve bear a certain proportion to the size of the boiler?

Ans. Because if the valve is too large it is liable to be blown off when raised by excessive pressure, and if too small then it will not relieve the boiler in time to prevent an explosion

Ques. Can you give the rules for size best proportioned?

Ans. Rankine's rule for the dimensions of safety valves is: Multiply the number of pounds evaporated per hour by .006 and the product will be the area in square inches of the valve. The United States steamboat inspection law requires for the common lever valve one square inch of area of valve for every two square feet of area of grate surface. A rule adopted by the Philadelphia Department of Steam Engine and Boiler Inspection is: 1. Multiply the area of grate in square feet by the number 22.5. 2. Add the number 8.62 to the pressure allowed per square inch. Divide (1) by (2) and the quotient will be the area of the valve in square inches.

Ques. How would you figure for 36 feet of grate surface with 80 lbs. pressure?

Ans. 36 sq. feet of grate $\times$ 22.5 = 810.0. Pressure allowed 80 lbs. + 8.62 = 88.62; 810 $\div$ 88.62 = 9.14 or a valve having a diameter of 3.4″.

Ques. What three elements enter into each calculation relating to the safety valve?

Ans. 1, The number of square inches on the face of the valve and the pressure of the steam; 2, the weight of the lever and valve in lbs; 3, the amount of the weight and its position on the arm of the lever.*

Ques. How do you find the square inches of a valve, the diameter being known?

Ans. By multiplying the square of the diameter of the circle by the decimal .7854.

Ques. How would you figure the pressure on a 3 inch valve with 100 lbs. boiler pressure?

Ans. Thus— $3 \times 3 = 9$ in.
$9 \times .7854 = 7.068$ area.
$7.068 \times 100 = 706.8$ lbs.

Ques. What is the Lever and what are its essential points?

Ans. Of the six mechanical powers (pully, wheel, screw, etc.) the lever is the first in the list.

There are three essentials in the lever—1, the fulcrum, or prop; 2, the power; and 3, the weight; or, differently stated, 1, the point on which the bar, or lever, turns (the prop, or fulcrum); 2, the place

* The weight of the lever and valve is of so little importance in the matter of pressure that examining engineers usually omit it from their questions.

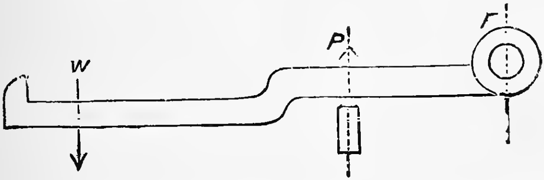
where the power is applied ; and 3, the point where the weight is applied.*

Ques. How many classes or kinds of levers are there ?

Ans. There are three classes of the lever, numbered according to the relative position of the fulcrum ; the safety valve lever is a lever of the third kind.

Ques. What is the method of calculating the power of the lever ?

Ans. The same calculation applies to each of the three classes of levers.



Rule for Calculating Levers.

The force (P) multiplied by its distance from the fulcrum (F) is equal to the weight (W) multiplied by its distance from the fulcrum.

NOTE.—When two forces act upon each other by means of any machine, that which gives it motion is called THE POWER, and that which receives, the *weight* (WEIGHT). See illustration.

The calculations are to be made in inches for distances and in pounds for the forces and weights, and the calculations are made for the action of mechanical powers upon the supposition that their action is not affected by their own weight, or by friction and resistance.

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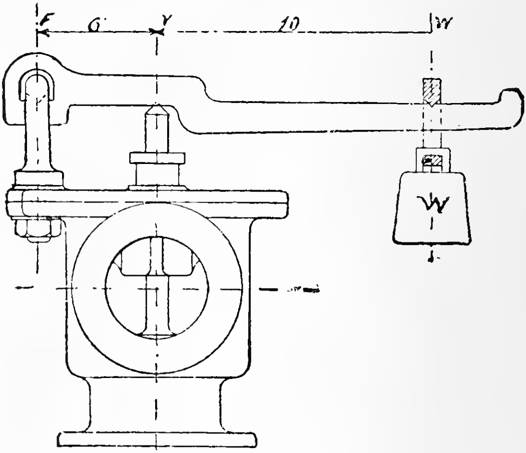
* In the safety valve lever *the prop* or fulcrum is the hinge-joint upon which the arm moves, the point where *the power* is applied is the conical valve being pressed upward by the steam, and the point where *the weight* is applied is on the arm of the lever.

Ques. What rule of arithmetic can be used to advantage in working safety valve problems?

Ans. The rule of three or rule of proportion.*



NOTE.—In the illustration F is the fulcrum; V is the point where the pressure is exerted; W is the weight; FV is 6 inches; and VW is 10 inches; therefore FW is 16 inches.

Ques. When the length of the lever, the weight and length of the short arm are known, give the rule for finding the steam pressure the weight will hold, give both rule and example.

Ans. RULE (One).

Multiply the length of the lever by the weight and divide the product by the length of the short arm.

* This "rule of three" is one of the most useful in the whole range of mathematics; a rule by which, when three numbers are given, a fourth number is found.

EXAMPLE.

The length of lever being 20 inches, the weight 20 lbs. on the end of it, and the short arm being 4 inches, then

The length of the lever,	20
Multiplied by the weight,	20
Divided by the short arm,	4)400
Answer,	100 lbs. resistance.*

Ques. When the diameter of the valve, the steam pressure, the length of the short arm and the weight are known, what is the rule to find the place to hang the weight? Give rule and example.

Ans. RULE (TWO).

Multiply the steam pressure in lbs. by the length of the short arm of the lever in inches, and divide the product by the weight of the ball.

EXAMPLE.

The diameter of the valve being $2\frac{1}{2}$ with steam at 60 lbs. gives the resistance to be overcome (*i. e.*, $2.5 \times 2.5 \times .7854 = 4\frac{9}{10}$ area of valve multiplied by 60 lbs) 294 lbs.; the short arm of the lever, 3 inches; weight of ball, 40 lbs. Now then :

The resistance (steam pressure) =	294
The short arm,	3
Divide by weight,	40)882
	22 05 inches of lever.

* This 100 would represent a valve area of $2\frac{1}{2}$ sq. in. at 40 lbs. pressure, etc.

Ques. When the steam pressure, the short arm, and the length of the lever are known, to find weight of ball needed. Give rule and example.

Ans. RULE (Three).

Multiply the steam pressure by the short arm, and divide the product by the length of the lever, the answer is the weight of the ball.

EXAMPLE.

The steam pressure (as in the last example) being 294, the short arm 2 inches, and the length of the lever 30 inches. Now then:

The steam pressure,	294
Multiplied by the short arm,	2
Divided by the lever,	30)588
Weight of ball needed,	19.6 lbs.

Ques. When the weight, length of lever and the steam pressure (resistance) are known, to find the length of the short arm. Give rule and example.

Ans. RULE (Four).

Multiply the length of the lever by the weight and divide the product by the steam pressure.

EXAMPLE.

The lever being 20 in., weight 20 lbs., steam pressure 100 lbs. Now then:

Length of lever,	20
Weight,	20
Divide by steam pressure,	100)400
Length of short arm,	4 inches *

* This 100 represents the total steam pressure on the valve—the example given being the reverse of the one for rule one.

Ques. If the ball is removed from the lever can there be any steam pressure on the boiler ?

Ans. Yes ; that due to the weight of the valve and stem. If they weigh, say 2 lbs., and the area of the valve is 7 sq. inches, then that would cause a pressure of $\frac{2}{7}$ of one lb. before the steam blows off.

Ques. What about the lever itself ?

Ans. The weight of the lever also operates the same way, except it is not a dead weight.

Ques. Explain why it is not a dead weight.

Ans. If you have a lever 30 inches long and it has the same size from end to end, its balancing center will be in the middle, or 15 inches. If the lever (bar) weighs 8 lbs. it will have the effect of hanging a ball of 8 lbs., 15 inches from the fulcrum.

Ques. Is there anything else which should be thought of in figuring the safety valve problems ?

Ans. Yes, a possible difference in the true diameter of the valve or connection pipes—the opening of the valve may be 2 inches diameter, but the circle of contact of face and seat may be 2½—this would make a difference of nearly ½ sq inch of area.*

* This difference need not be considered important in view of the factor of safety (6) usually allowed, *i. e.*, the boiler is made to withstand six times the ordinary pressure: BUT, it bears upon the question of omitting the weight of valve spindle and lever from common calculations.

TABLE OF PROPERTIES OF SATURATED STEAM.

Absolute pressure in lbs. per sq. in.	Temperature Fah.	Total heat of evaporation from water at 32° F.	Volume per lb. in cubic feet.
1	102.0	1113.0	330.36
2	126.4	1120.5	172.08
3	141.6	1125.1	117.52
4	153.1	1128.6	89.62
5	162.3	1131.4	72.66
6	170.1	1133.8	61 21
7	176.9	1135.9	52 94
8	183.0	1137.7	46.70
9	188.4	1139.4	41.80
10	193.3	1140.9	37.84
11	197.8	1142.3	34.63
12	202.0	1143.5	31.90
13	205.9	1144.7	29.57
14.7	212.0	1146.6	26.36
15	213.1	1146.9	25.85
16	216 3	1147.9	24.32
17	219.5	1148.9	22.96
18	222.5	1149.8	21.78
19	225.3	1150.6	20.70
20	228.0	1151.5	19.72
21	230.7	1152.3	18.84
22	233.3	1153.1	18.03
23	235.8	1153.9	17.26
24	238.2	1154.6	16.64
25	240.5	1155.3	16.00
26	242.7	1156.0	15.38
27	244 8	1156.6	14.86
28	246.8	1157.2	14.37
29	248.7	1157.8	13.90
30	250.5	1158.3	13.46

TABLE OF PROPERTIES OF SATURATED STEAM.—*Continued.**

Absolute pressure in lbs. per sq. in.	Temperature Fah.	Total heat of evaporation from water at 32° F.	Volume per lb. in cubic feet.
35	259.3	1161.0	11.65
40	267.0	1163.4	10.28
45	274.4	1165.6	9.18
50	281.0	1167.6	8 31
55	287.1	1170.0	7.61
60	292.6	1171.2	7.01
65	298.0	1172.7	6.49
70	302.8	1174.3	6.07
75	307.5	1175.7	5.68
80	312.1	1177.1	5.35
85	316.1	1178.4	5.05
90	320 3	1179.6	4.79
95	324.1	1180.8	4.55
100	327.7	1181.9	4.33
105	331.3	1182.4	4.14
110	334.6	1184.0	3.97
115	338.0	1184.5	3.80
120	341.1	1186.9	3.65
130	347.2	1187.9	3.38
140	352.9	1189.6	3.16
150	358.3	1191.2	2.96
160	363.4	1192.8	2.79
170	368.3	1194.3	2.63
180	383.0	1195.7	2.49
190	377.5	1197.1	2.37
200	381.8	1198.4	2.26
250	400.8	1204.2	1.83
300	417.1	1209.2	1.54
350	430.1	1212.2	1.33
400	445.0	1217.7	1.18

* Regnault.

SATURATED STEAM.

This has been defined on page 59 as the steam which rests upon the water within a boiler under pressure. Attention is now invited to the Tables (Regnault's) on the two preceding pages.

Let water at 32° be heated in a closed vessel, such as an ordinary steam boiler, containing space for the accumulation of steam, and let heat be gradually applied. Then the temperature of the water will gradually rise, and steam will be formed.

As the heat is increased, the temperature, pressure, and density, or weight per cubic foot, of the steam increase indefinitely, so long as the strength of the boiler is not exceeded ; and the relation between the temperature, pressure, and density always bears a certain fixed relation.

If heat is applied so as to maintain the temperature constant, the pressure and density remain constant also, and evaporation ceases. If a communication be opened between the boiler and engine, on escape of steam from the boiler the pressure is momentarily reduced and re evaporation commences rapidly. So long as the temperature is maintained, no sensible variation of pressure is noticeable in a boiler supplying steam to an engine.

It will be observed from the tables that saturated steam under a given pressure has a fixed temperature, also that the temperature and density increase with the pressure.

But it will be further noticed that the total heat increases in a very slow ratio compared with the pressure and temperature, there being only a very small increase of total heat per lb. of steam as the pressure increases. This is an important point in practice when considered in reference to coal consumption, for it shows that it is not much more costly in fuel to generate high-pressure steam than low-pressure steam, weight for weight; and that far more work can be obtained from it when used expansively than from the same weight of low-pressure steam—hence the economy of high-pressure steam.

In this connection it is interesting and important to compare the difference in the weight of water required to cool a given weight of water, with that required to cool the same weight of steam at the same temperature.

This is owing to the mysterious element which exists in steam under pressure—very like the unknown essential property of electricity—called latent heat. In generating water into steam there is absorbed about five and one-half times as much heat as is required under atmospheric pressure, to raise the temperature of the water from freezing point, 32° F., to boiling point, 212° F., an amount of heat which if the water were a fixed solid would, it is said, render it red hot by daylight. Tested by a thermometer the steam will show only 212°, but by experiment 1000°, nearly, have been

added, which is stored up in some hidden unaccountable way ; this is called the latent heat of steam.

There are two sorts or conditions of heat in the process of steam production operating upon water : 1, Sensible heat; 2, Latent or insensible heat ; hence the constituent or total heat of steam consists of its latent heat in addition to its sensible heat.

The appropriation of the heat expended in the generation of one pound of saturated steam at 212° F., from water supplied at 32° F., may be exhibited thus :—

To Generate one Pound of Steam at 212° F.

	Units of heat.		Mechanical equivalent in foot-pounds.	
The sensible heat:—				
1. To raise the temperature of the water from 32° to 212° F.,		180.9		139,655
The latent heat:—				
2. In the formation of steam	892.935		689,346	
3. In resisting the incumbent atmospheric pressure of 14.7 lbs. per square inch, or 2116.4 lbs. per square foot................	72.265		55,788	
		965.2		745,134
Total or constituent heat...		1146.1		884,789

Ques. What is the rule for finding the total heat in steam?

Ans. Multiply temperature or sensible heat of the steam by .3 ($\frac{3}{10}$) and add it to 1115°.

Ques. Give an example. What is the total and latent heat in steam that is 100 lbs. by the gauge?

Ans. 100 lbs. by the gauge is 115 gross, the 15 being, approximately, the weight of the atmosphere, and 115 gross has (by Table page 99) 338° of heat, hence,

$$338 \times .3 = 101.4 + 1115^\circ = 1216.4 = \text{total heat.}$$
$$338.0 = \text{sensible heat}$$
$$878\tfrac{4}{10} \text{ latent heat.*}$$

Ques. What are the total units of heat in steam of 212°?

Ans. $212^\circ \times .3 = 63.6 + 1115^\circ = 1178.6^\circ$ total heat.

Ques. What is the latent heat in this case?

Ans.
$$1178.6 = \text{total heat.}$$
$$212 = \text{sensible heat.}$$
$$966.6 = \text{latent heat.}$$

Ques. If the temperature of the feed water is known, what will be the number of units of heat to each lb. of water turned into steam? Give illustration.

Ques. If the steam in the boiler be 270° and the feed water be at 110° how many units of heat will it be necessary to add to this water to turn a lb. of it into steam?

Ans. $270 \times .3 = 81 + 1115 = 1196$, less feed water $110 = 1086$.

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* The small variation between the results in the examples and the figures in the Table is caused by greater detail of calculation in one more than the other. In the examples the air pressure is extended at 15 lbs. per square inch and in the Tables at 14.7.

Let it be remembered that a Thermal unit (expressed by T. U.) is the raising of 1 lb. of water 1 degree, and that the mechanical force existing in each unit is 772 lbs.

Ques. Which conducts heat best, dry steam or cloudy steam?

Ans. Dry steam is a poor conductor of heat as compared with either liquid water or cloudy steam, for after cloudy steam has received heat enough to make it dry or nearly dry it receives additional heat very slowly.

Ques. If a steam jacket is used, is the steam in the cylinder affected by the heat of the steam in the jacket?

Ans. It is assumed that the steam in the cylinder while expanding, receives just enough of heat from the steam in the jacket to prevent any appreciable part of it from condensing without superheating the steam in the cylinder.

Ques. Is there any gain in using steam at 100 lbs. and by expansion making the mean effective pressure 70 lbs. over, using steam of 70 lbs. throughout the entire stroke?

Ans. Using a cylinder with a volume of 1 cubic foot, and an initial pressure of 70 lbs. continued throughout the stroke, would be using, at each stroke, a cubic foot of 70 lb. steam, or a weight of .201 of a pound. Now, should the initial pressure be 100 lbs., a cut-off at 3/8 stroke would give the desired mean effective pressure of 70 lbs. and only use 3/8 cubic feet of steam. Now, 100 lbs. steam weighs .264 lb. per cubic foot; 3/8 cu. ft. therefore = .099, so that only .099 lb. would be used against .201 lb. of the lever pressure steam, as in the first case. Thus by working steam expansively you have a gain of .201 — .099 = .102 lb. at each ½ stroke.

PUMPS.

Upon the uniform operation of the pump depends the safety and comfort of the engineer, owner and employees, and indirectly of the success of the business with which "the plant" is connected.

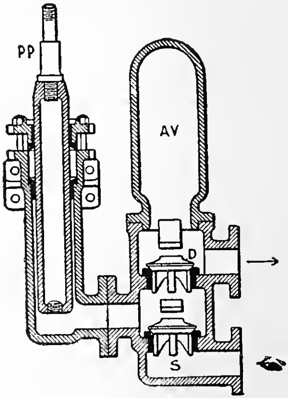
Pumps now raise, convey and deliver water, beer, molasses, acids, oils, and melted lead. They also handle such gases as air, ammonia, lighting gas and even oxygen.

Pumps are made in various forms and sizes ; they vary in design to suit their several uses, and are defined as rope, chain, diaphram, jet, centrifugal, rotary, oscillating, cylinder.

It is with the last named class with which the engineer has principally to become expert. Cylinder pumps are of two kinds, single acting and double acting.

The feed pump is used to supply the boiler, and it is required to supply a quantity of water at least equal to that evaporated and passed forward to the engine, together with leakage at safety valve, &c. ; and to provide also for emergencies it is usually made capable of supplying from 2 to 2½ times this quantity.

The action of the pump may be explained as follows: Suppose the plunger P at the bottom of its stroke, and the whole interior of the pump to be full of air. When the plunger rises the pressure of the suction valve S will be reduced, and the air in the supply pipe will lift the valve and flow into the barrel. The pressure of the air in the supply pipe is now less than before, and accordingly the pressure on the external surface of the water forces water up the pipe to such a height as to make the pressure inside the pipe balance the pressure outside. When the plunger returns the suction valve is closed by the pressure, and the air is forced out through the delivery valve D. Each time the stroke of the plunger is repeated, the water will rise in the supply pipe until at last it reaches and fills the barrel. Now, when the plunger returns, it forces water instead of air through the delivery valve.



THE PUMP.

The height of the column of water which will balance the pressure of the atmosphere is 34 ft.; that is, a column whose

weight is about 15 pounds per sq. in. In practice, however, the supply can never be drawn from a depth greater than about 25 ft.

The valves are prevented from rising above a certain height by stops shown in the figure. The lift of a valve should not exceed one-fourth of its diameter, for with this lift the whole of the water which passes through the valve seating can escape freely round the edge of the valve. Any further lift is therefore unnecessary.

Air vessels A, V, are chambers fitted to pumps close to and beyond the delivery valve. The air in the water collects in this vessel and forms a cushion or spring which enables the water to be delivered in a steady stream.

Ques. What is a single acting pump?

Ans. A single acting pump does its work through one end of the cylinder.

Ques. What is a double acting pump?

Ans. It is an engine and pump combined; in double acting pumps the motion of the piston in one direction causes an inflow of water, and a discharge at the same time, in the other; and on the return stroke the action is renewed as the discharge end becomes the suction end. The pump is thus double acting.

Ques. In a steam pump what are the two ends called?

Ans. The steam-end, which is a complete steam engine, and the water-end, into which the water is drawn, and from which it is discharged.

Ques. What is the connection between these ends—if any?

Ans. The water and steam ends are operated by a single rod, called the piston rod, which extends through from one end to the other—a pump so operated is a direct acting steam pump.

Ques. What is the force against which a pump works aside from the boiler pressure?

Ans. Gravity, or the attraction of the earth, which prevents the water from being lifted. This is shown in the fact that water can be led, or trailed an immense distance, limited only by the friction, by a pump.

Ques. What is the difference between a suction and a discharge valve?

Ans. The suction valve prevents the return of the water after it has entered the cylinder, and the discharge valve permits the outward passage of the water but does not allow its return.

Ques. Is it true that water is raised by suction?

Ans. No. Water is raised by pressure of air on the water outside the pump. The piston of the pump exhausts the air and the unbalanced weight of water causes it to rise within the pump or pipes supplying the pump.

Ques. What is the limit of this lift?

Ans. About 33 feet, because water of one inch area weighs $14\frac{7}{10}$ lbs., which is the weight of one

inch of air, at the sea level. Pumps must be in good order to lift 33 feet, and all pipes and valves must be perfectly air tight; pumps will give better satisfaction lifting from 22 to 25 feet.

Ques. In designing or purchasing pumps what is the safe rule as to capacity?

Ans. One should be selected capable of delivering one cubic foot of water per horse power per hour; or say, three pounds of water for each square foot of heating surface.

Ques. Why will not a pump lift hot water?

Ans. Because the vapor from the hot water fills the vacuum as fast as it is made by the piston and destroys its force, hence, no pump, however good, will lift hot water.

Ques. What is the best method of getting around this difficulty?

Ans. The pump should be placed below the supply, so that the water may flow into the valve chamber.

Ques. What is the most necessary condition for the satisfactory operation of a pump?

Ans. A full and steady supply of water. The pipe connections should in no case be smaller than the openings in the pump, and the suction lift and delivery pipes should be as straight and smooth on the inside as possible.

Ques. What is the advantage of the suction chamber ?

Ans. It prevents pounding—makes the action of the pump easy and uniform and enables the pump barrel to fill when the speed is high.

Ques. How should pumps be left in cold weather ?

Ans. Pumps should always be drained in cold weather, as freezing of water in pipes or cylinders is sure to burst them. Engineers should therefore be careful, and open the drip plugs or cocks, which are provided on all pumps for draining them.

Ques. What directions would you give as to setting up a pump ?

Ans. Use as few bends and valves as possible, and run every pipe in as direct line as practicable, and where convenient use full round bends rather than elbows, for valves, returns and elbows increase friction more rapidly than length of pipe ; never use pipes too small in diameter ; in long pipes this should be increased to allow for increased friction, especially in suction pipes.

Ques. In ordering a pump what is it for the interest of the purchaser for the builder to know ?

Ans. 1st. For what purpose is the pump to be used, and the average pressure of steam ?

2d. What is the liquid to be pumped, and is it hot or cold, clear or gritty, fresh, salt or acidulous ?

3d. What is the maximum quantity to be pumped per hour ?

4th. To what height is the liquid to be lifted by suction, also the height of discharge? What are the length and diameter of the suction and discharge pipes, and the number of elbows or turns?

Ques. Granted motion to the piston or plunger of a pump what is the only cause that makes it fail with an abundance of water?

Ans. A pump fails because it leaks—there can be no other reason, and the leak should be found and repaired. Leaky valves are common and should be ground; leaky plungers are frequent and should be re-turned in a lathe; leaky pistons sometimes exist and they should be repaired. The rod must be straight as far in as the packing and that must be kept free from dirt and sediment.

Ques. What should long suction pipes be provided with?

Ans. A foot valve, just above the strainer, in the well or pit.

Ques. What are direct acting steam pumps?

Ans. These have a single cylinder non-expanding and in larger sizes with double cylinders on the compound principle. These pumps may be divided into two classes; those having the valve gear on the outside where it can be seen, and those having the valve gear inside, no moving parts being visible when the pump is in operation except the piston rod.

Ques. What are direct acting duplex pumps?

Ans. These are two steam pumps placed side by side, so combined that the slide valve of each cylinder gets its motion from the opposite piston rod through a lever and rockshaft. The single direct acting and the duplex direct acting pumps are almost always double acting pumps, having the steam piston and the water piston at the two ends of the same rod. Therefore the steam pressure exerted upon the steam piston will be exerted upon the water piston direct.

Ques. What are pumping engines?

Ans. It has become customary to apply the term pumping engines to large reciprocating pumps used for supplying cities and towns with water, draining lakes and marshes, and other purposes, although strictly speaking any steam pump with its motor arranged in one machine is a pumping engine.

Ques. Which should have the larger area, the steam piston or water piston of the steam pump?

Ans. The steam piston should have about 2¾ times the area of the water piston. There being no mechanical purchase in favor of the steam piston, it must have the greater area of the two, otherwise the pressure on the water piston would equal the pressure on the steam piston and the pump would refuse to work. For this reason all boiler pumps have larger steam pistons than water pistons.

Ques. What rule would you give for area of steam piston?

Ans. Multiply area of water piston by 2.75.

Ques. How would you find the capacity of a water cylinder of a steam pump in gallons?

Ans. Multiply the area in inches by the length of stroke (this gives the capacity in cubic inches). Next divide by 231 (which is the cubical contents of a U. S. gallon) and the product is the capacity in U. S. gallons.

Ques. What is the rule for finding quantity of water pumped in one minute running at 100 feet of piston speed per minute?

Ans. Square the diameter of the water cylinder in inches and multiply by 4. The answer will be in gallons.

Ques. How do you find the horse-power necessary to pump water to a given height?

Ans. Multiply the total weight of the water in pounds by the height in feet and divide the product by 33,000.

Ques. How do you find the pressure in lbs., per square inch, of a column of water?

Ans. Multiply the height of the column of water in feet by .434.

Ques. What is the rule for finding the water capacity of a steam pump per hour?

Ans. 1st. Find the capacity of the pump in cubic inches, by multiplying the area by the inches in strokes, and by the fraction it is full.

2d. Find the cubic inches of water pumped per hour, by multiplying the contents of the pump by the strokes per minute and by 60, representing the minutes in an hour.

3d. Find the number of the cubic feet of water by dividing the cubic inches by 1,728.

Ques. In these rules have you made any allowance for "slippage" and friction?

Ans. No.

Ques. What must every feed pump be designed to do?

Ans. It must provide not only the water really needed for the work, but a large percentage additional to cover waste due to priming, condensation in the pipes, etc.

Ques. Give an idea of amount of slippage?

Ans. In well designed and well constructed steam pumps the "slippage" will be one-tenth and an allowance of one-quarter will be safe for the friction; but if the pump is old or badly designed or if the pump is working against a very high or a very low lift the net loss should be increased to twice the percentages given.

Ques. Can you give approximate rule for size of pipes for steam?

Ans. For the steam pipe divide the area of steam piston by 64.

For the exhaust pipe divide the area of steam piston by 32.

For the discharge pipe divide the area of plunger by 3.

For the suction pipe divide the area of plunger by 2.

But as the sizes of piping are of standard sizes, sizes can only be approximated, preference being given to the next size larger than the figures call for.

Ques. When pressure per square inch is shown by the guage, which is the greater pressure, that of water or steam?

Ans. There is no difference between the intensity of steam pressure and water pressure, a pound of pressure is a pound whether of steam or water.

Ques. What are pump valves made of?

Ans. They are made of brass, hard rubber, soft rubber, vulcanized fibre and wood.

Ques. What is to be said as to their size and "lift"?

Ans. The valves should be larger than the pipe, enough so as to give a clear waterway, the same area as the suction pipes. The lift of the valves should be as little as possible without causing too much frictional resistance to the water.

Ques. For leakage of water and steam priming, blowing off, loss by safety valve, etc., how much water for a stationary engine should be provided?

Ans. From double to two and one-half times the net feed water required by the engines.

Ques. How much should be allowed in marine engines?

Ans. To provide for the discharge of the brine, from three to four times of the net feed water should be provided.

Ques. Of what is water composed and in what proportions?

Ans. Water is composed of one volume of hydrogen to two of oxygen.

Ques. What are the cubic contents and weight of a cubic foot of water?

Ans. 1 cubic foot equals 7½ gallons (1,728 cubic inches) and weighs 62½ lbs. A gallon thus has 231 cubic inches and weighs 8½ lbs.

Ques. What is the rule for finding the water capacity of the horizontal steam boiler?

Ans. 1. Multiply two-thirds of the area of the head, in inches, by the length of the boiler in inches.

2. Deduct the area of a single tube multiplied by the number in the boiler, multiplied by the length in inches.

3. Divide by 231 to reduce the answer to gallons.

THE INJECTOR OR INSPIRATOR.

This boiler fixture was an invention of Gifford, and is one of the most peculiar and interesting appliances connected with the steam plant.

It is simply an instrument for allowing steam to rush from a boiler, and to suck up and mix with itself a stream of cold water, by which it is condensed, and to which it imparts so much of its own velocity, that the combined mass of water and condensed steam enters into and feeds the boiler.

Injectors are used also to pump out cisterns and drain basins and have even been used to pump out mines.

Questions and Answers Relating to the Steam Injector.

Ques. What is the main difference between the steam pump and the injector ?

Ans. The pump has moving parts and is a regular machine, while the injector has no moving mechanism whatever.

Ques. Whence comes the power, used in forcing water into the boiler by an injector ?

Ans. To the difference in the velocity of the escaping steam from a boiler under pressure and the velocity acquired by water from the same boiler and under the same pressure and at the same time.

Ques. About what is the difference in the speed of the two?

Ans. The steam has a velocity of sixteen or eighteen times that of the water—this varies with the pressure.

Ques. How should the instrument be connected?

Ans. It should be so placed that it will take steam from the highest point in the boiler. A valve should be put in the steam pipe just above the injector and a check and globe valve between it and the boiler, also a globe valve in the supply pipe; if the feed is delivered through a heater, place a check between it and the injector. It is better to have the suction pipe one size larger than the connection with the boiler, especially in case of a high lift.

Ques. What are essential to the successful operation of the instrument?

Ans. The suction pipe should be absolutely air-tight; the lift should not exceed 25 feet with a temperature of about 110 degrees and not more than 140 degrees for a low lift.

Ques. Will the injector work if the water supplied to it is too hot?

Ans. No. Because the colder the water the quicker and more thoroughly is the steam turned into water of condensation ready to join in the flow towards the boiler.

Ques. Does the injector "suck up" or lift the water that it forces into the boiler?

Ans. No more than a pump does; for both apparatuses simply remove the air from the supply pipes and the weight of the atmosphere pushes the water forward.

Ques. What are injector-nozzles?

Ans. They are tubes with ends rounded to receive and deliver the fluids with the least possible loss by friction and eddies.

Ques. What are double injectors?

Ans. They are those in which the delivery from one injector is made the supply of the second. The double injector makes use of two sets of nozzles, the "lifter" and "forcer." The lifter draws the water from the reservoir and delivers it to the forcer, which sends it into the boiler.

Ques. What is the exhaust steam injector?

Ans. It is different from others in that it uses the exhaust steam from a non-condensing engine.

Ques. What has been the objection to the greater adoption of this form of injector?

Ans. It carries over into the boiler the waste steam from the cylinder.

THE INDICATOR.

This device, invented by James Watt more than a century ago, is an ingenious tell-tale of what goes on in the steam-cylinder. A knowledge of its operation is necessary to obtain a high-grade license.

All indicators are practically of the same construction and act upon the same principle. Each consists of a small cylinder accurately bored out and fitted with a piston capable of working in the cylinder with little or no friction; the piston rod is attached to a pair of light levers, at the end of one of which is carried a pencil designed to move perpendicularly. The motion of the piston in the cylinder is $\frac{25}{32}$ of an inch and the area of the piston is exactly $\frac{1}{2}$ square inch.

The pressure of the steam is recorded by the pencil at all points of the stroke as the piston moves to and fro, on a piece of paper secured to a revolving drum. The motion of the piston is controlled by springs of known tension, several of which are furnished with each instrument; each spring is marked to show at what boiler pressure of steam it is to be used.

The only absolute information any indicator can convey, *whatever its form*, is the pressure in the cylinder of the engine; all the other information to be had from it comes

through a process of reasoning based upon experience and observation.

In order that the diagram should be correct it is essential, first, that the motion of the drum and paper shall coincide exactly with that of the engine-piston, and that the motion of the pencil shall also correspond with the other motions described.

Questions and Answers Relating to the Indicator.

Ques. What is an indicator card?

Ans. It is a paper wound round the cylinder of the indicator upon which the pencil has drawn the lines indicating the work done by the steam in the cylinder. The extreme length of the diagram may be 5¼ inches.

Ques. What is the steam-line?

Ans. It is the line on the card which shows the place of admission to beginning of cut-off.

Ques. What is the exhaust line?

Ans. It is that part of the diagram which shows the point of exhaust.

Ques. What is the expansion line?

Ans. It is that part showing the curve of expansion; *i. e.*, the movement between the cut-off and the exhaust.

Ques. What base line is always assumed in figuring the indicator card?

Ans. All figures are made from absolute vacuum, or $14\frac{7}{10}$ lbs. per sq. inch below atmospheric pressure.

Ques. Why?

Ans. For, from the line of absolute vacuum are made up all tables of weight, volume, expansion and all other properties of steam.

Ques. What four points does an indicator show?

Ans. Highest and lowest pressure, cut-off and lead.

Ques. How can you determine whether the steam is "wire-drawn"?

Ans. If the steam is "wire-drawn" the steam line will fall as the piston advances.

Ques. What is done when steam is cut-off at 6 inches?

Ans. When the piston has travelled 6 inches the valve closes, cutting off the live steam, and the remainder of the work in the cylinder is done by the expansion of the steam previously admitted.

Ques. What do you understand by the number of an indicator spring?

Ans. The number marked on a spring (several of which are furnished with each indicator) is designed to show the number of lbs. steam pressure on the boiler at which it is to be used: thus a 30 lb.

spring is one in which a pressure of 30 lbs. will cause the piston inside the indicator to rise one inch above the atmospheric line of the diagram.*

Ques. What is an indicator diagram?

Ans. It is the figure drawn by the pencil attached to the indicator from which the mean effective pressure in the cylinder is calculated.

Ques. How is this done?

Ans. By first dividing the diagram into ten equal spaces by drawing perpendicular lines to the atmospheric line called ordinates. Any number of ordinates may be used but it is customary to use 10.

2. The two end ordinates should be only half the distance from the ends of the diagram that they are from the next ordinate, because the ordinate is the middle of the space it occupies.

3. The ordinates being drawn their lengths are added together and the sum so obtained is divided by the number (10) which gives the average heighth.

4. If a 30 lb. spring has been used and the average heighth of the ordinates is 1½ inches, then the

* The strength of the spring is so adjusted as to cause the diagram to be about 2½ inches high, let the steam pressure be what it may. The following are the scales of springs to be used in the Thompson Indicator:

Scale of Spring.	Used for pressure above atmosphere if not more than
15 lbs.	21 lbs. per sq. in.
20 "	38 " " " "
30 "	94 " " " "
50 "	143 " " " "

average pressure of steam in the cylinder shown by the diagram is 45 lbs.

Ques. Having found the average pressure in the cylinder, how do you proceed to get the indicated horse power (I. H. P.)?

Ans. By multiplying the travel of the piston in feet and the area of the piston in inches; 2, multiplying the product by the mean average pressure in lbs.—in the case given; 45 lbs.—and dividing by 33,000.

Ques. What have you to say as to calculating, by the indicator, the amount of water and steam used from the boiler?

Ans. Experience shows that the full amount of water used cannot be accounted for, owing to its being unduly saturated, the cooling of the cylinder, etc., hence the calculations made are unsatisfactory.

Ques. Is there an easy way of getting the lengths of the ordinates?

Ans. Yes. Take a long strip of paper, say half an inch wide and 10 or 20 inches long, according to the nature of the card, mark a starting place on the edge near one end; then lay the strip of paper along the first dotted line, and mark off the length of that line; then lay it on the second space so as to add the length of the second line to the first line; and so on until the tenth (dotted line) ordinate is added, the whole being in one length, end to end.

Now take a rule and read off how many inches there are in the whole length, and divide them by ten.

Ques. What instrument has been invented and introduced to get the mean effective pressure as shown by a diagram ?

Ans. A planimeter. No skill or mathematical knowledge are necessary to use this instrument. The readings taken from a counter on the instrument give the area of the enclosed figure.

Ques. What is the difference between the Indicated Horse Power (I. H. P.) and the Effective Horse Power (E. H. P.)?

Ans. The effective horse power is the indicated horse power less the engine friction ; it is always less from the fact that the engine itself absorbs power.

Ques. What proportion of the indicated power does the engine consume ?

Ans. With well constructed engines and everything in good working order it is probably under ten per cent.—but with the ordinary unbalanced slide valves and bad construction one-third of the power is wasted.

Ques. Does a correct curve always show an economical engine ?

Ans. No, because a defective leakage may be the same on both sides—the leakage out may balance the leakage in—hence it must be carefully assured that the piston and valves are tight.

Ques. Does a defective diagram always indicate trouble ?

Ans. Yes, a diagram with an incorrect curve necessarily and infallibly shows a wasteful engine.

ELECTRICITY FOR ENGINEERS.

The latest developments of engineering are without a doubt along electric lines, and, in issuing a license for a steam plant where there is an electrical apparatus, the Examiner will insist upon some knowledge and practical experience in industrial electricity—and the devices employed to utilize it before granting a license.

The Electric current (so-called) is produced by a machine known as a Dynamo or Electric Generator ; this might be called the Steam Engine of Electricity as it simply transmits or carries along the power, produced elsewhere, to its specified work.

It is with the Dynamo that the Licensed engineer and his assistants has primarily to do, and it is necessary that he have a mastery of it—in the same degree that he has of his engine. It is true that in the Power Stations of Electric Railways and other large plants that Electricians, so ranked are constantly on watch, but it is generally true that the Engineer has charge of the Electric apparatus.

Next to the Dynamo the Engineer must be informed as to the Laws of the Transmission of the Electric Current—in practical language he must understand "Wiring."

The recent great advance in the practical development of Electricity has come from the discovery of the Electric Motor

—which is simply a Dynamo reversed—while the Dynamo is run by a belt or other mechanical means, the Motor is run by the electric current. A practical acquaintance with one answers for both the Dynamo and the Motor, although there are some points of difference necessary to be known.

What is electricity is a question often asked, but which has never yet been satisfactorily answered. It is one of the unexplained existences which, like latent heat, are known to be, but aside from their mighty and beneficial accomplishments might as well remain unknown.

How electricity is "gathered" and how it is utilized in some of the many machines now in use is the limit of necessary knowledge concerning it.

It is well to remember at the beginning that magnetism is almost indentical with electricity, and that the way in which a small magnet will attract and hold a bit of iron or steel (a tack or nail) is the A B C of the science. Next, that iron or steel are the principal metals (with copper wire) with which the greatest as well as the least of the electrical problems are worked out to a commercial and industrial success.

Questions and Answers Relating to Electricity and Electric Machines.

Ques. What is an electric current ?

Ans. It is something which seems to flow along or through the conducting wires ; although not known as to its nature it is freely called the electric current.

Ques. How many kinds of electricity are there?

Ans. One—although it is spoken of and treated as two, positive and negative.

Ques. How are these designated?

Ans. By the plus sign + for positive and the negative sign — for the negative electricity. These signs are very useful in designating the two.

Ques. How do these stand in relation to each other?

Ans. It is said that + electricity attracts — electricity, and that — electricity attracts + and the contrary, + repels +, — repels —.

Ques. How do these currents flow?

Ans. Positive (+) electricity and (—) electricity mean but a difference in pressure, always flowing from + to — as steam always flows through the steam pipe, engine and exhaust and never backward. It is impossible to generate a current of negative (—) electricity of a higher pressure than the (+) positive current.

Ques. What is a conductor?

Ans. Anything that will allow the electric current to flow freely through it. All the lines (wires) carrying electricity are conductors, hence anything which allows the free passage of electricity is a conductor, and anything which prevents the passage of electricity is a non-conductor.

Ques. Which is the most important?

Ans. It is just as necessary in practical work to have good non-conductors as it is to have good conductors.*

Ques. Name some of the conductors.

Ans. The ground is a good conductor, which fact often causes great "trouble." Water is a conductor, and if the wires and their supports are wet, and if there are any conducting substances that will allow the passage of current to the ground, there is trouble again. Other conductors are silver, copper, iron, etc.†

Ques. Name some non-conductors?

Ans. Dry air, glass, silk, asbestos, woolen and cotton cloth, dry paper, dry wood, oils.

Ques. What substances are generally used for non-conductors?

Ans. Cotton or silk, coated with paint, varnish or asphaltum; the cotton and silk are the non-conductors, and the varnish, etc., are put over all to keep away the moisture.

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* All substances will allow of the passage of some electricity, but as there are substances that offer a very strong resistance to its passage they are generally called insulators, or simply non-conductors.

† Silver is six times as good a conductor as iron, that is, if you take a silver wire and an iron wire the current will pass through the silver wire six times as easy as through iron. Lead will only conduct one-eleventh as well as silver.

Ques. What is one of the most important points in keeping up electric machines and circuits?

Ans. To keep the circuits well insulated and to allow no accumulation of oil and dirt around the machines to form a conducting substance. Lamps and dynamos must also be kept clean so that they work freely. Gas, moisture, and steam are to be watched for, as they all destroy the necessary insulation.

Ques. What is a dynamo-electric machine?

Ans. It is a machine driven by power, usually by steam or water, used to convert mechanical power into electrical energy.

Ques. Describe, generally, the construction of a dynamo.

Ans. There are various styles of dynamos, but they are all built upon similar principles. First, there is the magnet core, usually made of wrought iron; second, around the core are wound field coils —the field coil is copper wire generally insulated with soft cotton thread and double-wound; third, pole pieces, usually made of cast iron, into which the magnetic core is cast; the round space between the pole pieces is the magnetic field—so called because it is there that the lines of magnetic force cross from one pole to the other, and where the armature is placed; the pole pieces are united by, fifth, a "yoke," which completes the magnetic current; this is practically an electro magnet of the horseshoe form, with the wire wound on near the poles.

Ques. What is the meaning of the term insulated ?

Ans. This means removed from the sensation of touch, handling or feeling—rendered insensible to touch.

Ques. What is the object of insulating the wire of electro magnets ?

Ans. So as to form lines of travel for the magnetic force.

Ques. What would be the effect, if, through imperfect insulation, the wires of the magnetic coil came into contact at some point or other ?

Ans. It means so much loss, and if the insulation is too imperfect the whole circuit will have to be abandoned or newly insulated.

Ques. Is there any difference in the names of the poles in permanent and electro magnets ?

Ans. In a magnet the pole into which the lines of force are assumed to enter is called the south pole; the pole from which they are assumed to emerge is called the north pole—in other words the north pole is positive and the south pole negative.

Ques. What is a permanent magnet ?

Ans. It is a bar of U-shaped steel which continues magnetized for an indefinitely long time.

Ques. What is an electro magnet ?

Ans. It is a body of iron which becomes magnetized by the electric current passing around it

conducted by insulated wires—it is the opposite of a permanent magnet because upon stopping the machine the magnetic condition ceases.

Ques. What is a switch ?

Ans. A switch is a device used to make or break a circuit—the switch is so arranged that the hand will start it, while a powerful spring throws the switch open or closes it immediately.

Ques. What is a brush ?

Ans. This consists of a quantity of straight copper wires laid side by side, soldered together at one end and held in a suitable clamp ; two layers of wires are often thus united in a single brush.

Brushes are also made of broad strips of springy copper, slit for a short distance, so as to touch at several points.

Ques. What is the object of slitting the brush ?

Ans. The subdividing of the spark at the contact.

Ques. What rule do you consider important relating to the brushes ?

Ans. A brush should never be lifted off the commutator while the dynamo is running.

Ques. When do the brushes cause "flashing" ?

Ans. When they are out of position, too far ahead or too far back or not set directly opposite each other ; if the brushes do not have sufficient contact, a machine will frequently flash.

Ques. What is the use of the commutator ?

Ans. The commutator or collector of a dynamo is used for changing the alternating currents, as produced in the armature, to continuous currents as delivered to the lines. The commutator transfers these currents, as they are formed, to the brushes, which convey them to the lines continuously in one direction.

Ques. What is the commutator?

Ans. In general, a cylinder made up of alternate sections of conducting and non-conducting substances, running parallel with the shaft of the machine upon which it turns.

Ques. What may be said about the trouble caused by the dynamo ?

Ans. In the commutator and brushes will be found the greater part of the difficulties that the engineer in charge of the dynamo has to contend with in his electric plant.

Ques. What is the difference between an incandescent light and an arc light ?

Ans. The incandescent* light is produced by passing electricity through a carbon ribbon or filament confined in a vacuum ; an arc light is produced by passing electricity through two carbon pencils slightly separated, in open air.

* Incandescent means white. The electricity passing between the points forms an "arc" or curved line. Hence the name, arc light.

Questions and Answers Relating to Gravity and Strength of Materials.

Ques. What is gravity?

Ans. It is an unexplained force which draws every particle of matter toward every other particle. It extends to all known bodies in the universe, from the smallest to the greatest.

Ques. What is specific gravity?

Ans. Every substance in nature has a weight specific—or peculiar—to itself. For example, pine wood has a certain weight and cast-iron has another certain weight, hence, the specific gravity of a body is its weight compared with the weight of another body taken as a standard.

Ques. What is the accepted standard for all solids and liquids?

Ans. Water.

Ques. What is the standard of comparison for all gases?

Ans. Air.

Ques. When we say that the specfic gravity of iron (wrought) is 7.688, what do we mean?

Ans. That it is seven times as heavy as water and $\frac{688}{1000}$ over.*

* The heaviest of all known substances is platinum, whose specific gravity is 22, water 1; and the lightest of all weighable bodies is hydrogen gas, whose specific gravity is $\frac{073}{1000}$, common air being 1, but air is 818 lighter than water. Hence, by calculation, it will be found that platinum is 247,000 times heavier than hydrogen, and a wide range is allowed to the various bodies which lie between these extremes.

Ques. How may weight be defined? What is it?

Ans. The weight of a body is the force it exerts in consequence of its gravity. We weigh a body by measuring the force required to hold it back, or to keep it from descending, hence weights are nothing more than measures of the force of gravity in different bodies.

Ques. What is that principle which holds bodies together called?

Ans. It is the strength of cohesion; this is the power residing in the minute particles of matter, called molecules, to cling together.

Ques. Name four ways in which this cohesion may be overcome in a bar of iron or piece of timber, and the common names of the forces used?

Ans. 1. The bar may be pulled asunder; resistance to this force is called *tensile strength.*

2. The iron may be crushed in the direction of its length. This is direct thrust or compression, and the resistance to it is called the *crushing strength.*

3. The bar may be bent or broken from the direction of the middle or side. This is transverse strain or flexion, and resistance to it is called *transverse strength.*

4. The bar may be twisted off; this is torsion; resistance to it is *tortional strength.*

Ques. Define stress and strain.

Ans. Any bending or breaking pressure is a stress; its effect on the piece is a strain; hence the

strength of a solid piece or body is the total resistance it can oppose to strain in that direction.

Ques. What is the Hydrometer?

Ans. It is an instrument constructed for the especial purpose of ascertaining the specific gravities of liquids.

Ques. How may the specific gravity of solids be found?

Ans. Advantage may be taken of the important fact that when a body is wholly immersed in water, it displaces a bulk of that liquid exactly equal to its own, hence the difference of its weight in water from that of its weight in air must be the weight of an equal bulk of water.

Ques. What is a Salinometer?

Ans. It is a glass or metal instrument, by means of which the density of water is ascertained. In plain language it is a salt measure or hydrometer.

Ques. What is the amount of salt held in solution in sea water?

Ans. One thirty-third ($\frac{1}{33}$). This quantity is called one degree, and if the water of a marine boiler tested by the instrument shows $\frac{2}{33}$, it is expressed by saying "two degrees", if $\frac{3}{33}$, then three degrees, etc.

Ques. How are the Salinometers graduated?

Ans. Some into 33ds, and some into 32ds, each, representing about five ounces of salt to a gallon of water.*

* **Note**, *i. e.*, each 33d has 502 salt. $\frac{2}{33}$ has 1,002, $\frac{3}{33}$ has 1,502, etc.

Ques. In the use of the Salinometer where should care be used?

Ans. They should be used on water taken from the boiler almost as soon as it ceases to boil, as 200° is the usual temperature at which these instruments are tested, and as the density of fluids vary according to their temperature.

TABLE OF SPECIFIC GRAVITIES.

Iron (cast)	7.207	Charcoal	.441
" (wrought)	7.688	Brick	1.900
Steel (soft)	7.780	Clay	1.930
" (tempered)	7.840	Common Soil	1.984
Lead (cast)	11.400	Emery	4.000
" (sheet)	11.407	Glass	3.248
Brass (cast)	8.384	Grindstone	2.143
" (wire drawn)	8.544	Gypsum	2.168
Copper (sheet)	8.767	Lime	2.720
" (cast)	8.607	Granite	2.625
Gold (cast)	19.238	Marble	2.708
" (hammered)	19.361	Mica	2.800
" (22 carats)	17.481	Millstone	2.484
" (20 ")	15.709	Nitre	1.900
Silver (pure, cast)	10.474	Porcelain	2.385
" (hammered)	10.511	Phosphorus	1.770
Mercury (60°)	13.580	Pumice Stone	.915
Tin	7.293	Salt	2.130
Zinc (cast)	7.215	Sand	1.800
Bronze (gun metal)	8.700	Slate	2.672
Coal (Bituminous)	1.256	Sulphur	2.033
" (Anthracite)	1.436 / 1.640		

HORSE POWER (H. P.)

The capacity of work of a steam engine, a steam boiler, or of a whole steam plant is reckoned in horse power. The abbreviation of the term is H. P.

A horse power is 33,000 foot-pounds, or in other words, 33,000 pounds lifted 1 foot high in 1 minute, or 550 pounds lifted 1 foot in 1 second of time, hence

A foot-pound is one pound moved upward one foot. Example, work done by lifting 30 pounds through a height of 50 feet = 1,500 foot-pounds.

While, by means of the Indicator, the horse power of the steam engine can be determined to a nicety, the horse power of the steam boiler is almost an unknown quantity; it has been agreed upon, however, to consider the evaporation of 30 lbs. of water in 1 hour to be the standard of efficiency.*

Ques. What are the three kinds of horse power spoken and written about, which engineers should learn to distinguish ?

Ans. Nominal, Indicated and Effective.

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* The several tests made on the boilers used in the recent Chicago Exposition tend to prove that there has been no improvement in the maximum efficiency of boilers since 1876. But boilers are now made which carry high pressure as safely as were the pressures of 1876 by the boilers then made.

Ques. What is the difference between these ?

Ans. The nominal (N. H. P.) is only used as a general statement describing the dimensions of a steam engine for convenience of makers and purchasers of steam engine. 2d, the indicated (I. H. P.) is the "calculated" work done within the cylinder. 3d, the effective (E. H. P.) is the work an engine can do after deducting the amount required to drive the engine when it is running unloaded. The letters in brackets show the abbreviations of the terms.

Ques. How is the horse power of the boiler best determined ?*

Ans. The only sure method is by the actual measurement of the water evaporated.

Ques. In getting this measurement what precautions should be taken ?

Ans. Even when the amount of water introduced and the quantities passed off from the boiler are accurately known, there yet remains a doubt as to how much has been actually evaporated, and how much may have passed off in priming, unless the trial has been conducted with the boiler open to the atmosphere. To have the boiler thus open appears to be the only condition under which accuracy can be insured, unless a suitable apparatus can be provided for accurately measuring the weight and temperature of all the steam and water given off, when the boiler is working above atmospheric pressure.

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* For the rule for calculating the horse power of the Steam Engine, see pages 79 and 80.

Ques. Can any boiler be said to be free from priming?

Ans. There are very few boilers which do not prime more or less, and the quantity of water passed off in this way is quite considerable.

Ques. In view of these facts, can there be any accurate results obtained in boiler tests?

Ans. Unless the amount of water passed over with the steam by priming or foaming, when working under pressure, can be accurately ascertained, the evaporative results are not to be relied upon, however careful in other respects the trial may have been conducted.

Ques. Is the intensity of boiling itself constant?

Ans. It is not, as the heat is ever varying during the intervals between firing, and the difference in height is thus dependant and changeable.

Ques. What is the ordinary shop rule for estimating the horse power of the horizontal tubular boiler?

Ans. It is customary to consider fifteen square feet when exposed to the heat as being a horse power, and it is figured by the following:

Rule for Estimating the Horse Power of Horizontal Tubular Steam Boilers.

Find the square feet of heating surface of the shell, heads and tubes, and divide by 15: the answer is the nominal horse power.

ICE MAKING AND REFRIGERATION.

The connection between steam engineering and refrigeration is equally intimate as that which exists between engineering and electricity.

Both refrigeration and electricity in their practical application to the service of mankind demand the highest engineering skill, and it goes without saying that the engineer who is an expert in either of these widening lines of progress will receive comparatively the highest pecuniary return for his service.

That buildings will be soon cooled and ventilated in an artificial manner is assured by the high efficiency now attained by mechanical refrigerating machines ; some modification of the methods now employed in cold storage houses will be adopted for buildings, and as steam will be the actuating force, engineers must necessarily be employed in the care and operation of the machinery. This makes it desirable that the engineer should become as thoroughly posted as possible, regarding the principles and operation of the various mechanical refrigerating systems now in use, as well as those which will hereafter be developed, and he will find it greatly to his advantage to do so.

The principles governing artificial refrigeration are simple and are becoming familiar to many engineers, yet many

engineers understand the practical workings of the machines better than they do the principles upon which they operate—in view of the large future opening to this comparatively new industry it were well to unite the two.

A few easy definitions at the introduction of the subject may make the path of instruction plainer.

A refrigerant is anything which abates the sensation of heat, or cools.

To refrigerate is to cool ; to make cold ; to allay the heat of —

A refrigerating-machine is a machine for the artificial production of cold.

Refrigeration is specifically the operation of cooling various substances by artificial processes, and

Chemical refrigeration is effected by the use of freezing mixtures, which have the property of producing a sufficient degree of cold to freeze liquids.

Mechanical Refrigeration, in its strictest sense, is the conversion of heat into work by the expansion of a volume of gas or vapor, which performs work during the act of expansion ; in a broader sense, it is a process of refrigeration in which the cycle of heat changes is only partly produced by mechanical action, the mechanical part of the process being wholly confined to compressing the gas or vapor while liquifying it under the action of cold and pressure.

Every refrigerating apparatus consists of three parts, viz.:

1. The power (an engine), and gas (ammonia) pumps which compress the gas to a liquifying pressure.

2. A condenser in which the gas is cooled and changed to a liquid.

3. A system of evaporating coils, in which the liquid ammonia is expanded into a gaseous state and thus cools the surrounding space by the absorption of heat.

The refrigerating agent better than any known substance which has proved most advantageous is ammonia. This chemical boils at 40° *below* zero—as water boils at 212° *above* zero—thus assuring a low temperature without resorting to very low pressures.

Questions and Answers Relating to Refrigeration.

Ques. What is anhydrous ammonia?

Ans. The word anhydrous means "free from water": ammonia unmixed with water is sometimes called dry ammonia.

Ques. What are the advantages of ammonia over other fluids for refrigeration?

Ans. Its great stability, its non-inflamibility and non-explosiveness; it does not have the slightest effect on iron and steel, even when mixed with water, so that the machinery and piping which convey and circulate it are never in the least degree corroded.

Ques. What is the standard of cold production?

Ans. It is the weight of the gas circulated through the system and not the volume of gas.

Ques. How much cold can be produced from a pound of coal ?

Ans. Numerous tests have shown that with a fairly constructed refrigerating machine a melting capacity equal to that of 16 to 48 lbs. of ice can be obtained from a lb. of coal.*

Ques. What is the Brine system of refrigeration ?

Ans. In the Brine system one or more tanks of salt water are used, in which the evaporating coils are submerged, and the liquid ammonia, allowed to expand within the coils, assumes its original gaseous condition and in doing so absorbs the heat from the surrounding brine, reducing it to any reauired temperature.

Ques. In ice making how is the brine tank arranged ?

Ans. It is arranged to receive galvanized sheet iron cans containing fresh water, which remain in the brine until their contents are frozen into solid blocks of ice.

Ques. What is the direct expansion system ?

Ans. In the direct expansion system the ammonia expands directly in coils placed in the rooms to be cooled.

Ques. Which system (brine or direct expansion) is mostly used, and why ?

Ans. The brine system, because the brine tanks afford a considerable reservoir of cold which may be

* The wide difference given is shown by the tests and it will be found that the capacity varies with the conditions.

drawn upon in an emergency; another strong reason is that there is less risk of loss in the cooling rooms from escaped ammonia from leaking pipes; still another reason for preferring the brine system is because the whole system of the ammonia gas circulation is confined to one room or department and directly under the control of the engineer.

Ques. In the brine system how is the brine circulated? Describe the process.

Ans. It is accomplished by a special pump described as the brine circulating pump, which forces it through the pipes arranged in the rooms to be cooled, from which it returns to the tank to be re-cooled and continually used over again, through an endless round of cooling and warming.

Ques. Is the brine circulation quite independent of the gas circulation?

Ans. Yes, the only spot they come in contact is in the brine tank; here the cold ammonia gas extracts the heat from the brine as it flows through the tank; the two circulation systems do not come in nearer contact than that.

Ques. How is the cooling effected in the direct expansion system?

Ans. In the direct expansion system the ammonia expands directly in coils placed in the rooms to be cooled, the pipes being stronger but in other respects similar to those used in the brine circulation; in this system the brine pump is omitted.

Ques. What is the difference between a submerged condenser and an open air condenser?

Ans. In one plan the system of pipes is sunk in a tank containing water and in the other the pipes are exposed to the air and water sprinkled over them.

Ques. In either plan or method what is the common result?

Ans. The water extracts the heat from the pipes, being under the requisite pressure the ammonia is cooled to the temperature of the condensing water, and becoming liquified, is ready for use.

Ques. What other principal system of refrigeration is in use? Describe it.

Ans. The absorption system. This consists in a different arrangement of 1, the power, 2, the condenser, and 3, the evaporating coils, as mentioned on page 142.*

Ques. What are the parts of the absorption system specially called?

Ans. 1. The Generator. 2. The Ammonia Pump. 3. The Absorber. 4. The Condensing Tank. 5. Weak Liquor Tank. 6. The Equalizer. 7. The Freezing Tank. 8. The Cooling Tank. 9. Receiver for Ammonia.

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* These are mentioned on page 142 as essential to all systems of refrigeration.

Ques. What refrigerant is mostly used in the absorption system?

Ans. Ammonia largely reduced and mixed with water so that it is 26 per cent. strong—called properly, aqua-ammonia.

Ques. Upon what chemical law is the absorption system based?

Ans. Upon that which allows ammonia to boil into gas at 40 degrees below zero, while water is unaffected until 212 degrees is reached; the ammonia and water are thereby capable of being separated and thus made to perform continuous work.

Ques. What is the expansion valve?

Ans. It is that which controls the supply of ammonia to the evaporating coils.

Ques. What advantage is to be gained by the use of the device called "the agitator"?

Ans. Its use is to secure uniform freezing, which is accomplished by continually circulating and agitating the bath—this is sometimes done by the use of a centrifugal pump, which draws the brine from one end at the bottom and discharging in the other end at the top.

Ques. What is the cycle or circle of the ammonia in its two forms through its round of use and re-use?

Ans. 1. Compression. 2. Condensation. 3 Expansion. In order to render the operation continu-

ous these three are connected together, the gas passing through the system in the order named.

Ques. To what extent is the ammonia compressed?

Ans. From 125 to 175 lbs. per square inch, depending upon the temperature of the condensing water used, either mechanically or otherwise, in order to prepare it for the second operation–expressed more plainly, "heat is squeezed out of the gas.

Ques. How about the condensation?

Ans. The heat developed or "squeezed out" in the compression is withdrawn from the compressed gas by forcing it through coils of pipe while they are in contact with cold water—the heat being transferred to the water surrounding the coils.*

Ques. Of what does the expansion side consist and what is its operation?

Ans. The expansion side generally consists of coils of pipe, in which the gas re-expands and performs the refrigerating work; through these pipes the ammonia gas is drawn by the pumps at a pressure varying from 10 to 30 lbs. above that of the atmosphere.

Ques. Where do the "parts" meet?

Ans. The liquified gas is allowed to flow to a stop-cock having a minute opening which separates the compression from the expansion sides.

* When this point is reached the gas is ready to assume the liquid condition, and in so doing, is ready to give off additional heat to the surrounding water.

Ques. What are air machines ?

Ans. Machines that use air instead of ammonia; cold can be generated by the expansion of air ; air becomes heated under compression and will cool down again during compression. Air machines are generally used on ship-board where machines of comparatively small capacities are needed.

Ques. What are the objections to air machines ?

Ans. Their large coal consumption, which is eight to ten times that of good ammonia-compression machines—besides this the compressing-pumps are very large, the friction to operate them is great and the loss by leakage around the piston becomes considerable in course of time.

Ques. What is a double-acting compressor ?

Ans. One which handles the gas on both the upward and downward stroke.

Ques. What are its advantages ?

Ans. The friction will be the same for all the working parts, while double the work is being effected.

Ques. What is the greatest trouble to be overcome in refrigerating machinery ?

Ans. Leakage.

Ques. What should be one of the first rules as to the machinery and appliances ?

Ans. They should be kept clean and in good order ; means should be provided for cleaning the entire distilling system by steam.

HEAT AND WORK.

Without heat there would be no steam engine nor steam boiler, neither engineer or fireman.

The services of the engineer are chiefly devoted to changing heat into work; the heat which is carried to the engine in the steam is either transformed into useful work, or it passes away to waste in various ways, and the sum of the heat usefully employed plus the heat which is wasted always equals exactly the heat which was applied.

This is owing to a fundamental principle in nature that, just as matter can neither be created nor destroyed, though it may be made to assume different forms, visible or invisible, so energy, whether heat energy or any other, cannot be destroyed. It may take a variety of different forms, but the sum total of the energy remains the same. This principle is called the principle of the "conservation of energy."

The temperature of a body indicates how hot or how cold the body is.

We must not fail, however, to distinguish the temperature of a body from the quantity of heat in a body. Thus, if a cup of water be dipped out of a pailful of water, the temperature of the water is the same throughout, but the quantity of heat varies as the weight of water in each vessel.

Before quantities of heat can be measured we must have a unit of heat, just as we require a unit of length. Namely; the inch or foot in order to measure distance, or the pound or ton in order to measure weight.

The unit of heat is the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit when at a normal temperature.

Heat is transferable from one body to another, that is, one body can heat another by becoming less hot itself; thus, the furnace heat is transferred to the boiler plates, thence to the water and steam, and finally to the piston, in the driving of which heat is changed into work.

The natural condition of heat is a condition of energy, that is of a condition to effect changes—of coal into gas, of water into steam—and steam into work.

Ques. What is the mechanical equivalent of heat?

Ans. The amount of heat necessary to raise 1 lb. water from or near its freezing point (32°) one degree, is equivalent to the mechanical power which will raise 772 lbs. through a height of one foot.

Ques. How can we express units of heat as units of work?

Ans. Multiply the units of heat by 772.

Ques. How does this question of heat and work affect the engineer?

Ans. The whole business of the engineer is the superintendence of machines by means of which the conversion of heat may be carried out.

Ques. **What is a thermometer for and how does it act?**

Ans. Thermometers are used to indicate temperature, and they do so by the rise and fall of a little column of mercury enclosed in a tube of very fine bore, and having a small bulb at the bottom containing a store of mercury.

Ques. How does this show change of heat or temperature?

Ans. If the thermometer be warmed by any means, the mercury expands and tends to occupy a larger volume, and the column therefore rises in the stem of the tube; or, if the thermometer be cooled, the mercury will contract or diminish in volume, and the column will shorten or fall. A graduated numbered scale is affixed and the smallest change in temperature shown by the movement of the surface of the column is thus very easily detected.

Ques. How is the thermometer scale divided or graduated?

Ans. The instrument is placed in melting ice, and the point to which the mercury falls is marked the freezing point. It is then put in boiling water exposed to the air and the point to which the mercury column rises is marked the boiling point. The distance between these two points on the most commonly used thermometer, the Fahrenheit, is divided into 180 equal parts or degrees.

On the Centigrade thermometer the distance between these two marks is divided into 100 equal spaces or degrees—the word Centigrade is derived

from the two words meaning a grading by the hundred.

In the Reaumur scale, the same distance is divided into 80 degrees.

Ques. What is the position of zero on these scales?

Ans. The last two make the freezing point zero, while the Fahrenheit makes the freezing point 32° and thus the zero is $180° + 32°$, or 212° below boiling point, and temperatures are measured from zero up and down the scale.

Ques. What is meant by the term "energy"?

Ans. It may be defined as the power of doing work. When heat is applied to water it confers upon the steam which is produced the power of doing work, such as driving the piston from one end of the cylinder to the other, against a resistance.

Ques. What is specific heat?

Ans. It is the heat required to raise the temperature of a substance one degree, as compared with the heat necessary to raise the temperature of an equal weight of water one degree.

The specific heat of bodies varies very considerably, as will be seen from the following table:

Table of Specific Heat.

Water	=1.000
Cast Iron	=0.130
Steel	=0.118
Wrought Iron	=0.113
Copper	=0.100
Bismuth	=0.031
Lead	=0.031
Mercury	=0.033
Coal	=0.241

MEASURES AND WEIGHTS.

A large proportion of time is taken up in counting, in measuring and in weighing, and an engineer's success in the path of advancement is largely influenced by his readiness in these.

To avoid disputes there needs to be a certain well agreed upon standard, both of weights and measures, by which all will agree to be governed.

This agreed standard for each operation is called *the unit.*

Ques. What is the unit or measure of time ?

Ans. A minute.

Ques. What is the unit of arithmetical calculations ?

Ans. The figure (1) one.

Ques. What is the unit of pressure ?

Ans. The pressure of the atmosphere at the level of the sea. $14\frac{7}{10}$ lbs. to the square inch.

Ques. What is the unit of work ?

Ans. The foot-pound, which is the force required to lift one pound one foot high. 33,000 of these make one horse-power when executed in the unit of time (one minute).

Ques. What is the unit of heat ?

Ans. It is the heat required to raise one pound of water one degree—or say, one pound of water from 32° to 33°.

STEAM HEATING AND VENTILATION.

No small proportion of engineers' positions are retained, after being secured, by a practical familiarity with the care and management of the heating and ventilating apparatus; it is true that nearly always this apparatus is furnished, as to plan and detail, by the architect, yet the engineer must operate it to the satisfaction of the owner of the steam plant, or lose his situation

Hence it follows that no engineer will be granted a license to run a steam plant, where there is an extensive system of heating, unless he shows by his answers that he is capable of its management and understands, somewhat, the principles upon which it acts.

A system of heating and ventilation should, in the first place be simple, so that the average engineer shall be competent to operate it. It should be of sufficient capacity to do the heating required for all the space. and it should be safe, durable and economical.

In planning and in the management of the apparatus, both the heating and ventilation should be considered as one—they are inseparable and together form a complete whole; the apparatus should warm the air in an enclosed space to a temperature conducive to comfort and health, *and supply a volume of air sufficient to maintain a sanitary standard of purity;* both conditions—heating and ventilation—must be

controllable and constant, with the air deliveries so made that no complaint can be found with the engineer-in-charge.

In heating and ventilating the natural laws which govern must be regarded, otherwise all applications will be experimental, thus:

1. Air occupies space the same as solids and liquids, but because it is invisible it is not so regarded.

2. Cold air falls because of its density and heated air rises because of its rarity.

3. A given volume of air occupies a given space; a like volume cannot occupy the same space at the same time.

4. A volume of air can be delivered into a room only equal to the quantity displaced therefrom; when a space is full it can hold no more.

Ventilation is a substitution of fresh air for foul; it should be a gradual, constant and complete changing of the air in a room or structure.

The piping of a mill or factory or workshop was, comparatively, a few years ago, an easy task. To-day high buildings, with hundreds of business offices, government buildings with elaborate equipment and furniture, art institutes and museums with treasures and relics, mansions and cottages, are being warmed by special systems studied out by the mechanical engineer and master steam-fitter.

The systems are becoming intricate; they require drawings, planning, accurate measurements and calculations on areas and capacities, mechanical knowledge of steam and water, of pipes, furnaces, boilers, valves, fittings and those other adjuncts which have become necessary in the extensive use

of steam and hot water. In short, there is a great deal to be learned concerning present methods, and a great deal more to be learned in the future, as experience, invention and improvement will show.

It is, therefore, time for this branch of business--steam and hot water heating—to be recognized as one worthy of attention, investigation and study.

Questions and Answers Relating to Heating and Ventilation.

Ques. What is a very important principle to be observed in arranging a system of piping?

Ans. They should be so designed that there is a gradual slant from feed to return, with no air or water "pockets" and nothing to be in the way of a thorough circulation.

Ques. How should the fire surface of a boiler be proportioned to the quantity of pipe to be heated?

Ans. The extent of surface which a boiler should expose to the fire should be proportional to the quantity of pipe to be heated, and a small apparatus should have more surface of boiler in proportion to length of pipe than a larger one, as the fire is less intense and burns to less advantage in a small furnace than in a large one. It is more economical to

work with larger surface of boiler at moderate heat than to keep the boiler at its maximum temperature.

Ques. In taking charge of a new plant, what is the first thing to be done by the engineer?

Ans. To ascertain the exact course, size and operation of the steam, water, drain and other pipes.

Ques. Why is it necessary to do this so soon?

Ans. Because the boilers cannot be supplied with water even, nor blown off without the pipes being in order, nor steam taken to the engine nor distributed in a heating system without proper connections. Besides, it is well to do the most difficult thing first—the piping, being largely out of sight, is most difficult to inspect—more so than the engine, boilers or pumps.

Ques. Name some of the essentials to an efficient system of piping?

Ans. Pipes and valves should be of sufficient size to carry the full pressure of the boiler to the engine; elbows with a long turn are best, and T's are to be avoided, if possible. Pipes of proper size and easy bends are essential to economy.

Ques. What other matter relating to the piping is essential to economy?

Ans. The covering of all pipes by some good non-conducting substance, as condensation in the pipes when uncovered or partly covered increases greatly the cylinder condensation. This covering is

as important in warm as in cold weather, as steam 80 to 100 lbs. pressure has a temperature of 325 to 342 degrees of heat.

Ques. What is well to be known by an engineer relating to steam fitting and piping?

Ans. It is almost a necessity to know the names and uses of pipe fitter's tools, to be familiar with the different fittings and styles of valves, sizes, etc.

Ques. What are some of the fittings? Name a few of them.

Ans. Gaskets, nipples, steam and water unions, couplings, ells, lock nuts, off-setts, coils, radiators, steam traps, headers.

Ques. What is the very best non-conductor of heat?

Ans. Confined air—hence the best composition for steam pipes is that which has the largest quantity of confined air mixed with the material of which it is composed.

Ques. In pipe covering what two dangers must be guarded against?

Ans. The danger of fire, and second, that there are no currents of air formed between the pipe and the covering.

Ques. What is the latest idea in regard to ventilation?

Ans. That the best results are only to be had by a mechanical system, extracting the air and replacing it by fresh supplies—hence the increasing use of exhaust fans and blowers driven by various motors.

THE SMOKE PROBLEM.

Much vexatious litigation has been caused by the "smoke nuisance", so denominated in the ordinances passed by many cities; there has been a lively controversy between the officials and steam-users as to, first, the possibility and, second, the practicability of preventing smoke from issuing from the tops of the chimneys of steam plants. Many proprietors have been called to the bar of justice and fined for the offence, and not a few engineers have been threatened with arrest; at times both engineers and owners have been summoned to plead guilty or not guilty to the crime of smoke production.

That smoke can be absolutely prevented is proved by the operations of gas works, which yearly converts into gas, coke, tar, etc., millions of tons of bituminous coal without smoke.

The smokeless combustion of powdered coal, which has recently become an important fact in Europe, is greatly facilitated by the adoption of a new automatic mechanism and other arrangements. The fuel, instead of being introduced in the ordinary manner, is first ground to a powder, and, in place of the ordinary boiler fire-box, there is a combustion chamber in the form of a closed furnace lined with firebrick, and having an injector similar in construction to those used in oil burning furnaces. This chamber has two openings, one on the centre line and in the place of the usual

furnace fire door and the other on the opposite side. The orifice of the nozzle is placed in the latter aperture and throws a constant stream of fuel into the chamber, the nozzle being so located that it scatters the powder throughout the whole space of the firebox ; when the powder is once ignited, which is very readily done by first raising the lining to a high temperature by an open fire, the combustion continues in an intense and regular manner under the action of the current of air which carries it in. This current is regulated by the amount of powder required for the production of the heat led off to the boiler and the evaporation of the weight of steam demanded.

It may thus be seen that the question is not one of possibility but of practicability or economy; it being allowed that smoke prevention cannot be economically effected, then the

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English towns are more troubled by the smoke nuisance than any of those of our own country. The absolute abatement of the smoke being economically impossible, the cities have adopted ordinances to control and mimimize the nuisance. Thus Manchester, for example, has a city law which permits of the continuous emission of black smoke from any factory for one minute each half hour. Oldham allows nine minutes per hour. St. Helens, Newcastle-on-Tyne and Leeds, five minutes. At Birmingham the inspectors watch the chimney for an hour; they report the way in which the smoke is emitted, whether continuous or at intervals. For a first offense, or where a long time has elapsed between offenses, letters of caution are sent out. Sheffield allows six minutes in the hour, but where there are not more than three steam boilers and no furnaces, four minutes in the hour only. At Stoke-on-Trent if black smoke is emitted for a longer period than fifteen minutes, proceedings are taken. Bolton allows two and a half minutes in the half hour. In this connection it may be of interest to state that the Manchester Association has caused 1827 half-hourly observations to be made of various chimneys of the members, and the result of these observations showed that black smoke issued for 3224 minutes, an average of one minute forty-six seconds per half hour.

problem is as to a medium effect. Attention is called to the foot note regarding the practice obtained in England in dealing with the question.

"Human nature has not," said recently a distinguished lecturer, "is not, nor will it ever, be able to dole out the exact equivalent of air necessary for the complete consumption of each fresh charge of coals on the furnace grate." One of the reasons given was, "that coals differed so much in the quantity of their constituents as to make the above impossible."

In an investigation made by the lecturer, data was collected of the number of tons of coal consumed in a given time by thirteen puddling furnaces, and also of the color of the smoke emitted from the same. About 30,000 cubic feet of smoke gases were emitted every seventy seconds, of which the speaker declared that, "he was willing to forfeit any reasonable sum of money, if any one could prove that there was more than one part by weight of unburnt fuel in 2,680 parts, owing to rarefaction and the smoke on the average being only of a light brown color."

One point made is not without its pertinence in the present crusade against the smoke nuisance, and it is given as stated regarding some unreasonable prosecutions made of offenders: "If people more generally knew what the composition of smoke was, manufacturers would not in many cases be persecuted and prosecuted as at present, and authorities would exercise their discretionary powers in a more sensible and lenient manner." It need hardly be said that in very many instances of offense this criticism is not without its weight.

Questions and Answers Relating to the Prevention of Smoke.

Ques. What is the first requisite in the solution of the smoke problem?

Ans. Its formation should be prevented at the start, as the after-combustion or burning of smoke is almost impossible and quite the reverse of economical.

Ques. Give the generally accepted practice in prevention of smoke.

Ans. A high furnace temperature is most essential and this is best secured by a good draft; second, ample space in the furnace or combustion chamber for the mixture of the products of combustion (gases), mixed with, third, a due proportion of air; this must be supplied in some common sense manner, either through perforations in the furnace door or through minute openings in the bridge or side walls.

Ques. Where must the air be otherwise supplied?

Ans. Through the grate bars.

Ques. What proportion of air space should there be between the bars?

Ans. Generally speaking, 50 per cent., although this amount may be increased for large size, hard and lump, bituminous coal; for pea or nut coal the distance between the bars must be less.

Ques. What are some of the principal difficulties in the way of smoke prevention?

Ans. The worst trouble comes from uneven chimney draft, and again the varying qualities of coal which require different quantities of air-admixture.

Ques. Is there any difference made in the quantity of smoke by having too much or too little air?

Ans. Yes, either too much or too little air causes imperfect combustion—hence the smoke.

Ques. If the exact quantity of air needed was supplied to the furnace, would there be any smoke?

Ans. Not any to be observed. It may be said thus—with no air absolutely no combustion; with right quantity—then perfect combustion; with too much or too little then—smoke.

Computations usually made of stack capacity assume the chimney gases to be of the same specific gravity as air. This is not true, as when combustion is complete the gases are really a mixture of carbonic acid gas, nitrogen and steam; the proportions varying with different coals. As these require different amounts of air, the varying weights of the gases of combusiion cause a difference in the draft power of the same chimney. It is rare that just the proper amount of air is admitted, and there is a loss when the amount is too little or too great. Very often there is a surplus of air, reaching sometimes as high as 100 per cent.

ARITHMETICAL SIGNS.

There are various characters or marks used in arithmetical computations, to denote several of the operations and propositions, the chief of which are as follows :

$=$ *Equal to.* The sign of equality ; as 100 cents=$1, signifies that 100 cents are equal to one dollar.

$-$ *Minus*, or *Less.* The sign of subtraction ; as $8-2=6$; that is, 8, less 2, is equal to 6.

$+$ *Plus*, or *More.* The sign of addition ; as $4+5=9$; that is, 4, added to 5, is equal to 9.

$\times$ *Multiplied by.* The sign of multiplication ; as $6\times6=36$; that is, 6, multiplied by 6, is equal to 36.

$\div$ *Divided by.* The sign of division ; as $12\div3=4$; that is, 12, divided by 3, is equal to 4.

: is to
: : so is
. to
} The signs of proportion ; as 2 : 4 : : 8 : 16 ; that is, as 2 is to 4, so is 8 to 16.

$7-2+5=10$. Shows that the difference between 7 and 2, added to 5, is equal to 10.

^{2} added to a number, signifies that the number is to be *squared ;* thus : 6^2, means that 6 is to be multiplied by 6.

^{3} added to a number, signifies that the number is to be *cubed ;* thus : $5_3=5\times5\times5=125$. The *index*, or *power*, is the number of times a number is to be multiplied by itself, and is shown by a small figure placed at the right of the number to be raised, and a little elevated.

The *bar* signifies that all the numbers under it are to be taken together ; as $\overline{7+4}-3=8$; or, $5\times\overline{6+4}=50$. The parenthesis ( ) is sometimes used in place of the bar.

SUMMARY OF ARITHMETIC.

The following abridgment of several of the rules of arithmetic, often referred to in elementary books on mechanical science, are here inserted for the convenience of reference. These rules and examples are given merely to refresh the memory, it being taken for granted that the reader has already acquainted himself with the principles of common arithmetic. They will, howe er, be found serviceable, both as a convenience of reference, and to give some insight to the subjects on which they treat.

DECIMAL FRACTIONS.

A decimal fraction derives its name from the Latin *decem*, "ten," which denotes the nature of its numbers, representing the parts of an integral quantity, divided into a tenfold proportion. It has for its denominator a UNIT, or whole thing, as a gallon, a pound, a yard, &c., and is supposed to be divided into ten equal parts, called tenths ; those tenths into ten equal parts, called hundredths, and so on, without end.

The denominator of a decimal being always known to consist of a unit, with as many ciphers annexed as the numerator has places, is never expressed, being understood to be 10, 100, 1000, &c., according as the numerator consists of 1, 2, 3, or more figures. Thus : $\frac{2}{10}$ $\frac{24}{100}$ $\frac{125}{1000}$ &c., the numerators only are written with a dot or comma before them, thus ·2 ·24 ·125.

The use of the dot (·) is to separate the decimal from the whole numbers.

The first figure on the right of the decimal point is in the place of tenths, the second in the place of hundredths, the third in the place of thousandths, &c., always decreasing from the left towards the right in a tenfold ratio, as in the following

TABLE.

&c., &c.	Tens of Millions.	Millions.	Hundreds of Thousands.	Tens of Thousands.	Thousands.	Hundreds.	Tens.	Units.	Decimal point.	Tenths.	Hundredths.	Thousandths.	Ten Thousandths.	Hundred Thousandths.	Millionths.	Ten Millionths.	&c., &c.
	5	5	5	5	5	5	5	5	·	5	5	5	5	5	5	5	
			Ascending.										Descending				

A cipher placed on the left hand of a decimal decreases its value in a tenfold ratio by removing it farther from the decimal point. But annexing a cipher to any decimal does not alter its value at all. Thus 0·4 is ten times the value of 0·04, and a hundred times 0·004. But 0·7=0·70=0·700=0·7000, &c., as above remarked.

0·2 is read two-tenths.
0·25 " " twenty-five hundredths.
0·375 " " three hundred and seventy-five thousandths.
0·1876 " " one thousand eight hundred and seventy-six ten thousandths, and so on.

Mixed numbers consist of a whole number and a decimal; as 4·25 and 3·875.

Addition of Decimals.

Rule.—Arrange the numbers so that the decimal points shall be directly over each other, and then add as in whole numbers, and place the decimal point directly below all the other points.

FRACTIONS.

$\frac{5}{10}$	is the same as	·5	read 5 Tenths.
$\frac{7}{100}$	" "	·07	read 7 Hundredths.
$\frac{30}{1000}$	" "	·030	read 30 Thousandths.
$\frac{1248}{10000}$	" "	·1248	read 1248 Ten Thousandths.
$8\frac{6}{10}$	" "	8·6	read 8 and 6 Tenths.
$7\frac{8}{1000000}$	" "	7·000008	read 7 and 8 Millionths.
$84\frac{25}{100}$	" "	84·25	read 84 and 25 Hundredths.
$5\frac{6}{10000000}$	"	5·0000006	read 5 and 6 Ten Millionths.
480	" "	480·	read 480.
		585·5748086	read 585 and 5748086 Ten Millionths.

Subtraction of Decimals.

Rule.—Place the numbers directly under each other, according to their several values, as in addition; then subtract as in whole numbers, and point off the decimals, as in the last rule

Example.—Subtract 7·75 from 15·125.

$$\begin{array}{r} 15·125 \\ 7·75 \\ \hline 7·375 \end{array}$$ remainder.

Multiplication of Decimals.

Rule.—Place the factors under each other, and multiply them together as in whole nnmbers; then point off as many figures from the right hand of the product as there are decimal places in both factors, observing, if there be not enough, to annex as many ciphers to the left hand of the product as will supply the deficiency.

Example.—Multiply 3·625 by 2·75.

3·625×2·75=9·96875. Ans.

Division of Decimals.

Rule.—Prepare the decimal as directed for multiplication; divide as in whole numbers; cut off as many figures for decimals in the quotient as the number of decimals in the dividend exceeds the number in the divisor; and if the places in the quotient be not so many as the rule requires, supply the deficiency by annexing ciphers to the left hand of the quotient.

Example 1.—Divide 173·5425 by 3·75.

```
3·75)173·5425(46·27
     1500
     ----
      2354
      2250
      ----
       1042
        750
       ----
        2925
        2625
        ----
         300
```

Example 2.—Divide 63·50 by 4·25.

```
4·25)63·50(14·94
     425
     ----
     2100
     1700
     ----
      4000
      3825
      ----
       1750
       1700
```

RULE OF THREE, OR PROPORTION.

The Rule of Three teaches how to find a fourth proportional term to three given numbers.

The rule of three is either direct or inverse.

When more requires more, or less requires less, it is direct. Thus, if 5 barrels of beef cost $30, what will 12 barrels cost? Or, if 30 cubic inches of cast iron weigh 8 lbs., what will 378 cubic inches weigh?

The proportion in both of the above cases is direct, and the statement must be

As 5 : 30 : : 12 : 4th term $=72$ Ans.

30 : 8 : : 378 : " $=100\frac{4}{5}$ lbs. Ans.

When more requires less, or less requires more, the rule is inverse. Thus, if 3 men do a certain piece of work in 5 days, in how many days will 4 men do the like quantity? Or, if 12 men build a certain quantity of wall in 28 days, in how many days will 8 men perform the same work?

Here the proportion is inverse, and the statement must be

As: 4 : 5 : : 3 : 4th term $=3\frac{3}{4}$. Ans.
8 : 28 : : 12 : " $=42$. Ans.

The product of the second and third terms, divided by the first, always gives the fourth term.

Three numbers are necessary for a statement; and two of these must contain the supposition, and the third the demand.

Rule.—Of the three given numbers, place that for the third term which is of the same kind with the answer sought.

Then consider, from the nature of the question, whether the answer will be greater or less than this term. If the answer is to be greater, place the greater of the two numbers for the second term, and the less number for the first term; but if it is to be less, place the less of the two remaining numbers for the second term, and the greater for the first; and in either case multiply the second and third terms together, and divide the product by the first for the answer, which will always be of the same denomination as the third term.

NOTE.—If the first and second terms contain different denominations, they must both be reduced to the same denomination; and compound numbers to integers of the lowest denomination contained in it.

Example.—If 40 tons of iron cost \$450, what will 130 tons cost?

```
TONS. DOLLS.  TONS.
 40 : 450 : : 130
      130
     -----
     13500
     450
     ------
   4|0)5850|0
     ------
     1462·5 dollars.   Ans.
```

ARITHMETICAL PROGRESSION.

Arithmetical Progression is a series of numbers which succeed each other regularly, increasing or diminishing by a constant number or common difference :

As 1, 3, 5, 7, 9, &c. increasing series.
15, 12, 9, 6, 3, &c. decreasing series.

The numbers which form the series are called terms. The first and the last term are called the extremes, and the others are called the means.

In arithmetical progression, there are five things to be considered, viz.:

1, The first term.
2, The last term.
3, The common difference.
4, The number of terms.
5. The sum of all the terms

These quantities are so related to each other, that when any three of them are given, the remaining two can be found

Given the first term, the common difference, and the number of terms, to find the last term.

Rule.—Multiply the number of terms, less one, by the common difference, and to the product add the first term.

Example.—What is the 20th term of the arithmetical progression, whose first term is 1, the common difference $\frac{1}{2}$?

$$20-1=19 \text{ and } 19\times\tfrac{1}{2}=9\tfrac{1}{2}; \text{ and } 9\tfrac{1}{2}+1=10\tfrac{1}{2}. \quad \text{Ans.}$$

Given the number of terms and the extremes, to find the common difference.

Rule.—Divide the difference of the extremes by one less than the number of terms.

Example.—The extremes are 3 and 29, and the number of terms 14, required the common difference.

$$29-3=26; \text{ and } 26\div13=2. \quad \text{Ans.}$$

Given the common difference and the extremes, to find the number of terms.

Rule.—Divide the difference of the extremes by the common difference, and to the quotient add one.

Example.—The first term of an arithmetical progression is 11, the last term 88, and the common difference 7. What is the number of terms?

$$88-11=77; \text{ and } 77\div7=11; \ 11+1=12. \quad \text{Ans.}$$

Given the extremes and the number of terms, to find the sum of all the terms..

Rule.—Multiply half the sum of the extremes by the number of terms.

Example.—How many times does the hammer of a clock strike in 12 hours?

$$1+12=13 \text{ the sum of the extremes.}$$

$$\text{Then } \ 12\times(13\div2)=78. \quad \text{Ans.}$$

TO SET THE VALVES OF A CORLISS ENGINE.*

And make proper adjustment of valve gear and regulator, please read carefully and follow the instructions here given :

The Steam and Exhaust Valves.—Take off the back valve chest cover or bonnets and upon the bore of the seats you will find a mark which is in line with, or coincides with the closing edge of the port for that particular valve seat. Look upon the end of the valve and find a mark running towards the centre of the valve; this line coincides with the closing edge of valve. Note that in case of the exhaust valve, the valve controls the part leading into the exhaust passage and not the opening from the cylinder downward. The upper edge of the exhaust port is the closing edge and the outer edges of the steam ports are the closing edges.

The Wrist Plate—should now be looked over and you will find a mark upon the hub of the same, and corresponding marks upon the hub of the wrist plate bracket. Also marks which show the full extent of motion of the wrist plate when it is moved back and forth by the eccentric. The wrist plate should be located exactly central between the four valves and is so placed in the shop in building the

* These directions are given by E. P. Hampson to accompany the Eclipse Corliss Engine, and are sufficiently general to answer for any Corliss Engine.

machine, and all adjustments are made and valves properly set, but in taking apart for adjustment it may be possible that the adjustments may be distributed and need careful going over before attempting to start the engine for the first time.

TO TEST THE MARKS ON WRIST PLATE HUB—connect the eccentric rods and engage or drop the carrier rod back upon the wrist plate stud ; then turn the eccentric upon the shaft, the full extent of its throw or vibration each way, and observe if the marks upon the hub of wrist plate at full throw agree with the marks upon the bracket ; if not, disconnect the strap from eccentric rod, and adjust the screw on stub end by lengthening or shortening, as required, until the marks do agree on both extremes of movement. Now you are ready

TO SET THE VALVES.—Place the wrist plate in a vertical position (at the central mark) ; turn the valves around in their seats until the steam valves show by the closing edge marks upon their ends by comparison with the port line marks in the seats, that the steam-valve edges lap over or cover the ports $\frac{1}{4}$ of an inch for 18 inch bore of engine cylinder, $\frac{3}{8}$ for 24-inch cylinder, and $\frac{7}{16}$ for 30-inch cylinder. The exhaust valves should show from $\frac{1}{16}$ to $\frac{1}{8}$ lap, according to size of cylinder.

IN CONNECTING THE WRIST PLATE—see first that the cut-off latch is hooked on the stud or is engaged. Leave the plate and valves in this position and adjust the length of the wrist plate rods to suit the distances between the studs, or, in other words, connect the wrist plate and steam and exhaust valve

arms so the wrist plate stands at the central mark or vertical, and the steam and exhaust valve have the proper lap and opening as instructed, the proper amount of steam lap and exhaust opening being determined by the size of the engine.

To Make Final Adjustments.—Now you can drop the wrist plate carrier rod hook on the stud, place the engine upon the centre, knowing which way the engine shaft is to run, turn the eccentric upon the shaft, it being loose, in the same direction in which the shaft is to run, a little more than at right angles ahead of the crank or until the steam valve on the same end as the piston is just beginning to open, say $\frac{1}{32}$ of an inch—in this position secure the eccentric on the shaft by means of the set screws in the hub. (See in all cases that the steam valves are hooked up or engaged by the cut-off mechanism.) Then turn the engine on the opposite centre and see if the steam valve on that end has the same amount of opening ; if not, you can make the adjustment by lengthening or shortening the wrist plate rod attached to this valve.

To Adjust the Cut-Off, see that the governor and connections are put together properly, and block the governor about half way in the slot; then fasten the reach or cam rod lever so it stands about at right angles to a line drawn midway between the reach rods; then lengthen or shorten the reach rods until the cam or trip levers stand vertical or plumb. The governor and connections now occupy the proper relative positions, and it remains to make the

Exact Adjustment and to equalize the cut-off, so the same amount of steam is admitted at each end of the stroke.

Also, lower the governor and observe when the governor is down that the cut-off mechanism does not unhook but allows steam to be taken full stroke,* after which place the engine at, say $\frac{1}{5}$ of the stroke, which can be done by measuring upon the slide ways from each end and turning the engine (*with all parts connected up*) until crosshead is fair with the mark, then slowly raise the governor until the cut-off on the end taking steam trips or unhooks, and to insure this point being accurately determined, it is well to stand by with the hand pressing down upon the dash-pot rod; now block the governor in this position and try the cut-off on the other stroke same distance from the end. After a few trials back and forth and adjusting the length of the cam rods, the cut-off can be made to drop at precisely the same point of stroke. Take care to secure everything permanently when done.

THE DASH-POT ROD should be adjusted in length so the steam valve arm resting thereon, when the dash-pot plunger is home, or at the bottom of the pot, is in such a position that the latch is sure to hook over the latch stud, and the stud lays midway between the latch die and the closing shoulder. This will insure, on the other hand, the positive engagement of the latch, and on the other hand prevent the shoulder from jamming down upon the latch stud in steam arm. If the dash-pot rod is too short the latch will not hook on. Look out for this.

* Here we would say that it does not appear to be generally known that the Corliss valve motion, when properly made, is provided with a positive closing device which, in case the valve does not trip, positively closes the valve before piston reaches the end of the stroke.

The Dash-Pot is provided with a leather packing in the vacuum plunger underneath the dash-pot proper. This should be kept in good condition. To spread the packing introduce some liners of paper inside the flange or cup leather. When leather is adjusted just right the pot works promptly and softly. The air valve in the air opening is to regulate the amount of air cushion by turning the screw in the escape hole.

The Regulator Gag-Pot is used on Corliss engines to prevent over-sensitiveness of the governor, and to its response to trivial changes. Use only coal or kerosene oil in this pot, and remove one or more of the screws in the piston to give freedom of motion. *See that all parts of the governor move freely.*

Using a Steam Engine Indicator to test the correctness of valve setting is the most approved method known, and should be applied in cases where an indicator can be obtained. Recollect that to adjust the point of cut-off to take same amount of steam to each end, adjust the cam or reach rods. To give more or less lead adjust the wrist plate rods. Lengthening them increases the lap, and shortening them gives more lead. The same with the exhaust valves, the cushion or release being affected thereby. If the eccentric is properly set it is not necessary to disturb it in ordinary cases. In closing these directions, let us impress upon you the necessity of marking everything, so at a glance you can tell if it has been disturbed.

Emergency Rule for Setting Slide Valves.

If the eccentric slips around the shaft, or any other accident throws the valve-gear out of position, then,

1. Have some one roll the engine forward in the direction it runs until the crank is on the dead centre.

2. Open the cylinder cocks at each end.

3. Admit a small amount of steam into the steam chest by opening the throttle slightly.

4. Roll the eccentric forward, *in the direction the engine runs*, until steam escapes from the cylinder cock at the end where the valve should begin to open.

5. Screw your eccentric fast to the shaft.

6. Roll your crank around to the next centre, and ascertain if steam escapes at the same point, at the opposite end of the cylinder. If so, the valve is in position for service, until an opportunity occurs to open the steam-chest and examine the valve-gear.

Emergency Rule for Setting Duplex Pump Valves.

Take off the valve chest cover, push the piston to water end, mark the piston rod by tying a string at the gland, then push same piston to stem end and tie another string around it. Find the center between the two marks and move the piston until the centre mark reaches the gland where the first mark was made. After this is done see how the valve is for lead ; if equal at both ends your valve is set, if not, adjust your jam nuts to suit. Work the same way with the other piston.

A PRELIMINARY EXAMINATION CONDUCTED BY ONE'S SELF.

1. Can I build and maintain a fire with an intensity of heat sufficient to hold a working pressure of steam? 2. Can I fire with soft coal and prevent smoke issuing from my chimney in too large volumes? 3. Can I pack the valve stems, chest covers and piston rods of the engine and feed pump? 4. Can I line up shafting? 5. Can I lace up a belt in a suitable manner and run it on the pulley safely? 6. Do I understand, and can I replace the working points of the feed pump when they become worn? 7. Can I determine, by its action, whether pump is delivering water to the boiler or not? 8 If not, can I tell where the difficulty exists?

A chief engineer's position is no sinecure. It requires constant study, thought and action. It takes men of *hard* brains to fill soft situations, it also requires years of application for *brains* to harden, hence one too young or inexperienced should hesitate in accepting a position which they know they cannot possibly fill with mutual profit to themselves or the owners.

Elementary and Preliminary Questions by the Examining Engineer.

These questions are given as those frequently asked of the applicant upon his first appearance for examination.

1. Where and how long did you serve in the works at the making or at the repairing of engines and in what capacities?

2. How long have you served as fireman? How long have you been employed as an engineer, and where? 3. Give some further idea of the extent of your experience as an engineer. 4. What kind of engines are you familiar with? Marine or land, condensing or non-condensing, horizontal, compounds, etc.? 5. What defects in engines have come under your notice? 6. What caused these defects and how were they remedied? 7. With what description of boilers have you served? 8. Describe a horizontal tubular boiler. 9. Describe a vertical boiler. 10. What boiler defects have come under your notice and how have they been remedied? 11. Have you ever witnessed a steam boiler explosion, and if so, give the cause? 12. Give the names of the firms for whom you have served or vessels upon which you have been engaged? 13. What parts of the engine are usually of cast iron? 14. For what parts of an engine is steel sometimes used? 15. What are hand holes put in boilers for? 16. How often do you open them? 17. What is the shape of a man hole cover, and about what is its size? 18. What is priming in a boiler and what means are taken to prevent it?

NOTE.—A boilermaker says that never before have boiler materials been of better quality than they are to-day. A contrary belief is often expressed; but modern mastery of steel making has lessened the margin between good steel and inferior steel. The danger with boiler making is not poor steel, but poor workmanship. Badly spaced tubes, rivets and braces, plates too thin for the work, deficient safety attachments, and ill-proportioned settings are points where the ignorant or dishonest make a cheap and dangerous boiler.

U. S. GOVERNMENT RULES FOR THE SAFETY VALVE.

The following rules issued by the United States Board of of Supervising Inspectors, on account of changes in the rules for granting licenses to engineers of steam vessels, are entirely accurate for use in figuring the different problems relating to the safety valve.

To find the weight required to load a giveu safety-valve to blow at any specified pressure.

1. Measure the diameter of the valve, if is it not known, and from this compute its area exposed to pressure.

2. Weigh the valve and its spindle.* If it is not possible to do this, compute their weight from their dimensions as accurately as possible.

3. Weigh the lever, or compute its weight from its dimensions.

4. Ascertain the position of the centre of gravity of the lever by balancing it over a knife-edge, or some sharp-cornered article, and measuring the distance from the balancing point to the fulcrum.

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* To find the weight of the valve, spindle, lever, etc., proceed as follows: Take out the valve and spindle and weigh them and make a note of it, then put them back in place, connect the lever and drop it in place resting on the valve spindle, tie a string to the lever directly over the spindle, hook on the scales to the string and weigh the lever, to the weight of the lever add the weight of valve and spindle, or the weight may be found approximately by computation.

5. Measure the distance from the center of the valve to the fulcrum.

6. Measure the distance from the fulcrum to the center of the weight.

Then compute the required weight as follows :

1. Multiply the pressure in pounds per square inch at which the valve is to be set by the area of the valve in square inches; set the product aside and designate it "quantity No. 1."

2. Multiply the weight of the lever in pounds by the distance in inches of its center of gravity from the fulcrum ; divide the product by the distance in inches from the center of the valve to the fulcrum, and add to the quotient the weight of the valve and spindle in pounds; set the sum aside and designate it "quantity No. 2."

3. Divide the distance in inches from the center of the valve to the fulcrum by the distance, also expressed in inches, from the center of the weight to the fulcrum ; designate the quotient "quantity No. 3."

4. Subtract quantity No. 2 from No. 1, and multiply the difference by No. 3. The product will be the required weight in pounds.

To find the length of the lever, or distance from the fulcrum at which a given weight must be set to cause the valve to blow at any specified pressure.

The area of the valve in square inches, the weight of the valve, spindle and lever in pounds, the position of the center of gravity of the lever, and the distance from the center of

the valve of the fulcrum, must be known, as in the first example.

Then compute the required length as follows

1. Multiply the area of the valve in square inches by the pressure in pounds per square inch at which it is required to blow ; set the product aside, and designate it "No. 1."

2. Multiply the weight of the lever in pounds by the distance in inches of its center of gravity from the fulcrum ; divide the product by the distance in inches from the center of the valve to the fulcrum ; add to the quotient the weight of the valve and spindle ; set the sum aside, and designate it "No. 2."

3. Divide the distance in inches from the center of valve to fulcrum by the weight of the ball in pounds, and call the quotient "No. 3."

4. Subtract "No. 2" from "No. 1," and multiply the difference by "No. 3"; the product will express the distance in inches that the ball must be placed from the fulcrum to produce the required pressure.

To find at what pressure the safety valve will commence to blow when the weight and its position on the lever are known.

The weight of valve, lever, position of centre of gravity of lever, etc., must be known as in both the preceding examples.

Then compute the pressure at which the valve will blow, as follows :

Multiply the weight of the lever by the distance of its center of gravity from the fulcrum; add to this product that obtained by multiplying the weight of the ball by its distance

from the fulcrum ; divide the sum of these two products by the distance from the center of the valve to the fulcrum, and add to the quotient so obtained the weight of the valve and spindle. Divide the sum by the area of the valve ; the quotient will be the required blowing-off pressure in pounds per square inch.

EXAMPLE.

Suppose we have a safety valve, with a weight of 50 lbs. suspended 24 inches from the fulcrum ; say the lever weighs 6 lbs., gravity center (balancing point) 15 inches from the fulcrum, weight of valve and spindle 2 lbs., and its center 4 inches from the fulcrum, and the diameter of the valve 2 inches, at what pressure will the valve open ? Now, then:

Diameter of valve is 2 inches ; its square is $2\times2=4$; its area is $0.7854\times4=3.1416$; the weight of the ball is 50 lbs., its distance from fulcrum is 24 inches, and $50\times24=1,200$; the weight of lever is 6 lbs., the center of gravity is 15 inches from the fulcrum, and $15\times6=90$; the weight of the valve is 2 lbs., and its distance is 4 inches from fulcrum, and $4\times2=8$; the area of the valve is 3.1416, and its center is 4 inches from fulcrum, then $4\times3.1416=12.5664$, and $1200+90+8=1298$, and 1298 divided by $12.5664=103.3$ lbs., or the pressure at which the valve will open*.

* The "moment" or leverage of the steam is the total pressure acting upwards, multiplied by the distance in inches from the pivot to the valve-stem. The moment or leverage of the ball acting downwards is the total weight of the ball multipled by the distance in inches from the pivot to the center support of the ball. When, therefore, the moment of the steam, which acts upwards, exceeds both the dead weight of the lever and valve, and also the moment of the ball holding the valve down, then the valve rises and steam escapes.

U. S. GOVERNMENT RULES FOR EXAMINATIONS OF APPLICANTS FOR ENGINEERS' LICENSES.

It will be observed that in land service the engineer is examined with reference to his capacity to manage a particular steam plant, especially the steam generating apparatus. He is licensed to have charge of a particular "plant" and for a single year; but in the marine service, where the examinations are conducted by sworn officers of the U. S. Navy, the license is granted without reference to a particular craft, nor is it limited to time, except the candidate is subject to re-examination; the marine licenses, however, vary as to ocean and inland steamers, tug boats, etc.

Regulations Relating to Marine Engineers.

1. Before an original license is issued to any person to act as engineer, he must personally appear before some local board or a supervising inspector for examination; but upon the renewal of such license, when the distance from any local board or supervising inspector is such as to put the person holding the same to great inconvenience and expense to appear in person, he may, upon taking the oath of office be-

fore any person authorized to administer oaths, and forwarding the same, together with the license to be renewed, to the local board or supervising inspector of the district in which he resides or is employed, have the same renewed by the said inspectors, if no valid reason to the contrary be known to them; and they shall attach such oath to the stub end of the license, which is to be retained on file in their office. And inspectors are directed, when licenses are completed, to draw a broad pen and red ink mark through all unused spaces in the body thereof, so as to prevent, so far as possible, illegal interpolation after issue.

2. The classification of engineers on the lakes and seaboard shall be as follows:

CHIEF.

Chief engineer of ocean steamers.

Chief engineer of condensing lake, bay and sound steamers.

Chief engineer of non-condensing lake, bay and sound steamers.

Chief engineer of condensing river steamers.

Chief engineer of non-condensing river steamers.

Chief engineer of condensing freight, towing, and fishing steamers.

Chief engineer of non-condensing freight, towing, and fishing steamers.

Chief engineer of condensing steamers under one hundred tons.

Chief engineer of non-condensing steamers under one hundred tons.

Chief engineer of canal steamers.

FIRST ASSISTANT.

First assistant engineer of ocean steamers.

First assistant engineer of condensing lake, bay, and sound steamers.

First assistant engineer of non-condensing lake, bay, and sound steamers.

First assistant engineer of condensing river steamers.

First assistant engineer of non-condensing river steamers.

First assistant engineer of condensing freight, towing, and fishing steamers.

First assistant engineer of non-condensing freight, towing, and fishing steamers.

First assistant engineer of condensing steamers under one hundred tons.

First assistant engineer of non-condensing steamers under one hundred tons.

First assistant engineer of canal steamers.

SECOND ASSISTANT.

Second assistant engineer of ocean steamers.

Second assistant engineer of condensing lake, bay, and sound steamers.

Second assistant engineer of non-condensing lake, bay, and sound steamers.

Second assistant engineer of condensing river steamers.

Second assistant engineer of non-condensing river steamers.

Second assistant engineer of condensing freight, towing and fishing steamers.

Second assistant engineer of non-condensing freight, towing and fishing steamers.

Second assistant engineer of condensing steamers under one hundred tons.

Second assistant engineer of non-condensing steamers under one hundred tons.

THIRD ASSISTANT.

Third assistant engineer of ocean steamers.

Third assistant engineer of condensing lake, bay, and sound steamers.

Third assistant engineer of non-condensing lake, bay, and sound steamers.

Third assistant engineer of condensing river steamers.

Third assistant engineer of non-condensing river steamers.

Third assistant engineer of condensing freight, towing, and fishing steamers.

Third assistant engineer of non-condensing freight, towing and fishing steamers.

First, second, and third assistant engineers may act as such on any steamer of the grade of which they hold license, or as such assistant engineer on any steamer of a lower grade than those to which they hold a license.

Inspectors may designate upon the certificate of any chief or assistant engineer the tonnage of the vessel on which he may act.

3. Assistant engineers may act as chief engineers on high-pressure steamers of one hundred tons burden and under, of the class and tonnage, or particular steamer for which the inspectors, after a thorough examination, may find them qualified. In all cases where an assistant engineer is permitted to act as first (chief) engineer, the inspector shall state

on the face of his certificate of license the class and tonnage of steamers, or the particular steamer on which he may so act.

4. It shall be the duty of an engineer when he assumes charge of the boilers and machinery of a steamer, to forthwith thoroughly examine the same, and if he finds any part thereof in bad condition, caused by neglect or inattention on the part of his predecessor, he shall immediately report the facts to the local inspectors of the district, who shall thereupon investigate the matter, and if the former engineer has been culpably derelict of duty, they shall suspend or revoke his license.

5. No person shall receive an original license as engineer, or assistant engineer, except for special license on small pleasure steamers of ten tons and under, and ferry-boats navigated outside of ports of entry and delivery, who has not served at least three years in the engineer's department of a steam vessel.

Section 5. (Second paragraph amended.) *Provided,* That any person who has served as a regular machinist in a marine engine works for a period of not less than three years (not including any time he may have served as an apprentice, may be licensed as an engineer of steam vessels of one hundred tons and under, and for inferior grade of license above one hundred tons); and any person who has served for a period of not less than three years as a locomotive engineer stationary engineer, regular machinist in a locomotive or stationary engine works (apprentice machinist in an engine works), and *any person who has graduated* as a mechanical

engineer from a duly recognized school of technology, may be licensed to serve as engineer on steam vessels after having had not less than one year's experience in the engine department of a steam vessel, which experience must have been obtained within two years preceding the application (which fact must be verified by the certificate in writing of the licensed engineer or master under whom the applicant has served, said certificate to be filed with the application of the candidate), and no person shall receive license as above, except for special license, who is not able to determine the weight necessary to be placed on the lever of a safety valve (the diameter of valve, length of lever, and fulcrum being known) to withstand any given pressure of steam in a boiler, or who is not able to figure and determine the strain brought on the braces of a boiler with given pressure of steam, the position and distance apart of braces being known ; such knowledge to be determined by an examination in writing and the report of the examination filed with the application in the office of the local inspectors, and no engineer, or assistant engineer now holding a license shall have the grade of the same raised without possessing the above qualifications.

And no original license shall be granted any engineer, or assistant engineer, who cannot read and write, and does not understand the plain rules of arithmetic.

The Secretary of the Treasury has issued the following rules concerning the examination of applicants for the position of second assistant engineer in the United States revenue marine.

A candidate for an appointment as second assistant engineer must not be less than twenty-one nor more than thirty years of age; he must be of good moral character and correct habits; he must have worked not less than eighteen months in a machine shop and have had responsible charge of a steam engine, or else have served not less than that period in charge or assisting in the care and management of the machinery of a steam vessel in active service. Upon examination, he must be able to describe and sketch all the different parts of the marine steam engine and boilers, and explain their uses and mechanical operation, the manner of putting them in action, regulating their movements, and guarding against danger. He must write a fair legible hand, be well acquainted with arithmetic, simple mensuration, English orthography and composition, also with rudimentary mechanics and its practical applications; he must possess some skill in the use of ordinary hand tools, and have a fair practical knowledge of the nature of heat and steam, of the general laws in relation to the expansion of steam, of the uses of the indicator and interpretation of diagrams, of the chemistry of combustion and corrosion, of the composition of sea water and uses of the salinometer, and of the usual calculations to determine loss by blowing, gain by heat, and water necessary for condensation.

No person otherwise qualified will be commissioned as an engineer before he has shown his ability to perform duty at sea in a satisfactory manner for a period of at least six months. This service may either antedate or be acquired subsequent to an examination.

No person will be originally appointed to a higher grade than second assistant engineer, not until he shall have passed a physical and professional examination. The physical examination shall preceed the professional, and if a candidate be rejected physically, he will not be examined further. All professional examinations will be competitive in character, and applicants, who pass the minimum standard required in several subjects, will be placed upon the list of persons eligible for appointment, in the order of the excellence of their examinations, respectively. From this list appointments will be made in regular order, as vacancies may occur, until another examination.

No person will be designated for examination until he has filed in the department the necessary certificates showing his proper qualifications as to character, habits, and time or times of service, and the ability that has been displayed during such service.

Any person producing a false certificate of age, time of service, or character, of making false statement to a board of examination, will be dropped immediately.

Any person who, subsequent to his examination, may become disqualified from moral considerations, will not be appointed.

(MODEL OF)

CITY ORDINANCE RELATING TO ENGINEERS' LICENSES.

The following is given as a model of city regulations requiring examinations, and as nearly all State and city laws are substantially alike, this may suffice to indicate the legal requirements to be conformed to by the applicant. The full text of the law here given shows very clearly the responsibility of the system of licensing an engineer and the gravity with which it is regarded by the public :

SEC. 388. Any person desirous of being employed to take charge and control of any stationary engine, steam boiler, or other steam generating apparatus within the city of Cleveland, shall apply to the Examiner of Engineers for a blank application, which shall have been prepared by said Examiner of Engineers.

After said applicant shall have filled out said blank application, and shall have caused the same to be signed by three (3) reputable stationary engineers, who shall have obtained previously a license for said employment, he shall then apply to the said Examiner of Engineers, to be examined by the said Examiner of Engineers touching his qualifications for

such employment, and if the said Examiner of Engineers, after having made an examination, shall have found said applicant possessed of the necessary qualifications for said employment, he shall give said applicant a certificate to that effect.

On presentation of such certificate to the City Clerk, and the payment to said clerk of the sum of fifty (50) cents for the first issue of a license and twenty-five (25) cents for each subsequent issue thereof by such applicant, the said clerk shall issue to such applicant a license under the seal of said city, authorizing such applicant to take charge and control of a stationary engine, steam boiler, or other apparatus for generating steam, for the period of one year from the date of its issue, and the said clerk shall pay all moneys so received by him into the treasury of said city, to the credit of the general fund, provided, however, that said Examiner of Engineers shall issue no such license to any applicant who shall not have had one (1) year's practical experience in said employment, except in private dwelling houses.

SEC. 389. It shall be unlawful for any person or persons to take charge and control of any stationary engine, steam boiler, or other apparatus for generating steam, except in private dwelling houses, without having a license to do so, as provided in the foregoing section, which license shall be exposed to view in a conspicuous place in the room or place containing the boiler, generator, or engine of which such person is in charge; provided, however, that all licenses heretofore issued in pursuance of said original ordinance shall continue in force for the period for which they were issued.

It shall be unlawful for any person or persons, partnership or association, company or corporation, knowingly to employ or keep in their employ for the purpose of taking charge and control of any stationary engine, steam boiler, or other apparatus for generating steam, except in private dwelling houses as aforesaid, any stationary engineer or other person who has not been licensed as above provided and required.

SEC. 390. It is hereby made the special duty of every police officer or patrolman, and the superintendent of police is hereby instructed to give the said Examiner of Engineers all possible assistance to enforce the provisions of this chapter, and for this purpose the police shall have authority to enter any shop, factory, mill, store, warehouse, hotel or other building or structure in which a steam boiler or engine is located, and to demand to be shown the license of the engineer having charge of said steam boiler or engine.

SEC. 391. Whoever violates any of the provisions of this chapter shall be subject to prosecution before the Police Court of said City, and on conviction thereof be fined in any sum not less than ten dollars nor more than twenty dollars for the first offense, and not less than twenty dollars nor more than fifty dollars for the second and each subsequent offense.

LAWS RELATING TO THE INSPECTION OF STEAM BOILERS.

According to the laws of the State, every owner, agent or lessee, of a steam boiler or boilers, in the City of New York, shall annually report to the board of police, the location of said boiler or boilers, and, thereupon, the officers in command of the sanitary company shall detail a practical engineer, who shall proceed to inspect such steam boiler or boilers, and all apparatus and appliances connected therewith.

When a notice is received from any owner or agent that he has one or more boilers for inspection, a printed blank is returned to him stating that on the day named therein the boilers will be tested, and he is asked to make full preparation for the inspection by complying with the following rules :

Be ready to test at the above named time.

Have boiler filled with water to safety valve.

Have $1\frac{1}{2}$ inch connection.

Have steam gauge.

Steam allowed two-thirds amount of hydrostatic pressure.

The following have also been adopted by one or more Inspection Companies:

How to Prepare for Steam Boiler Inspection.

1. Haul fires and all ashes from furnaces and ash pits.

2. If time will permit, allow boiler and settings to cool gradually until there is no steam pressure, then allow water to run out of boilers. It is best that steam pressure should not exceed ten pounds if used to blow water out.

3. Inside of boiler should be washed and dried through manholes and handholes by hose service and wiping.

4. Keep safety valves and gauge cocks open.

5. Take off manhole and handhole plates as soon as possible after steam is out of boiler, that boiler may cool inside sufficiently for examination; also *keep all doors shut* about boilers and settings, *except the furnace and ash pit doors.* Keep *dampers* open in *pipes* and *chimneys.*

6. Have all ashes removed from under boilers, and fire surfaces of shell and heads swept clean.

7. Have spare packing ready for use on manhole and handhole plates, if the old packing is made useless in taking off or is burned. The boiler attendant is to take off and replace these plates.

8. Keep all windows and doors to boiler room open, after fires are hauled, so that boilers and settings may cool as quickly as possible.

9. Particular attention is called to Rule 5, respecting doors —which should be open and which closed—also arrangement

of damper. The importance of cooling the inside of the boiler by removal of manhole and handhole plates at the same time the outside is cooling, is in equalizing the process of contraction.

Issuing Certificates.

These conditions having been complied with, the boiler is thoroughly tested, and if it is deemed capable of doing the work required of it, a number by which it shall hereafter be known and designated is placed upon it in accordance with the city ordinance : Failure to comply with this provision is punishable by a fine of $25. A certificate of inspection is then given to the owner, for which a fee of $2 is paid.

This certificate sets forth that on the day named the boiler therein described was subject to a hydrostatic pressure of a certain number of pounds to the square inch. The certificate tells where the boiler was built, its style or character and "now appears to be in good condition and safe to sustain a working pressure of —— to the square inch. The safety valve has been set to said pressure." A duplicate of this certificate is posted in full view in the boiler room. In case the boiler does not stand the test to which it is subject, it must be immediately repaired and put in good working order before a certificate will be issued.

Applicants for licenses are very liable to be asked—to test their experience in and around steam boilers—some questions relating to their inspection ; hence the value of these extracts upon the subject.

IMPORTANT.

The following ten pages are undoubtedly the most valuable and instructive of any same number of pages in this volume. They indicate the path of advance in granting licenses for the future, and, with admirable modesty, the great benefits which have accrued from a wise and faithful administration of public law, controlling engineers' examinations and the granting of licenses. It will be happier times when the whole country is equally guarded and protected.

STEAM BOILER INSPECTION AND CERTIFICATION OF ENGINEERS.

BY THE SUPERINTENDENT, DEPARTMENT BOILER INSPECTION BROOKLYN, N. Y.

(*Extract.*)

In the city of Brooklyn the inspection of boilers is made by a corps of six inspectors. The hydrostatic test is applied, and wherever deemed necessary, a hammer test is added. Whenever defects are ascertained, they are caused to be remedied or the boiler condemned.

The inspection of steam boilers and the certification of engineers to manage and care for the same are subjects to which much thought has been given by the best engineers of the country. From the inception of the general idea of official boiler inspection to the present date, great strides

have been made by both national, state and municipal governments in bringing the system to perfection, and to throw around boilers under their supervision every safeguard that human ingenuity could devise.

The United States government, through its able corps of naval engineers, has done much to advance the interests of those engaged in this work, having systematized the work so that the best possible results are attained with the material at hand. The individual states are also gradually falling into line and are enacting laws providing for the needed inspection.

In the cities of New York and Brooklyn the laws governing boiler inspection are similar in general principle, while differing in some of the particulars. In both cities the bureaus of inspection are a branch of the police dapartment, responsible to the commissioner or commissioners of police. In the former city, officers are detailed for this work from the police force, after having given satisfactory evidence of their qualification for this duty, and are under a commanding officer of experience and discretion.

In the city of Brooklyn, while the inspectors are not members of the force, they are entitled to all the privileges and subject to the same discipline. The superintendent of steam boilers is a position provided for by statute, the qualifications for which are set forth explicitly, and the duties and authority expressed in such laws. The examination and grading of engineers is discretionary with him, and the steam plants in the city are classified and recorded in his office. The aim and desire of the department is to assist and

encourage the best skill among our engineers, thereby aiding the worthy and deserving men, as well as to provide for steam users the best material for the management of their several steam plants.

The Association of Boiler Inspectors of the United States and Canada, following the example set by the United States inspectors, hold annual meetings for the interchange of views and opinions as to the best method of boiler inspection. They have adopted rules which, while not legally binding upon its members as are the rules of the latter body, yet place a moral obligation for the carrying out of the same.

It is our proud privilege to be able to say that since the institution of the inspection of steam boilers in this city, there has been no explosion of a steam boiler that had previously been inspected by the department.

The inspectors are always on the alert, and arrests are frequently made for violation of our laws, and the courts by their actions sustain and strengthen the hands of the department in enforcing the law.

The engineers of this city are of great assistance to the department in the care of their several plants, and are ever ready to assist the department in its work. The steam users as well recognize the importance of the work, and it is the desire of the department while enforcing the law to conserve their interests wherever practicable. There are some imperfections in our laws that might be corrected, and some action will be taken in that direction to the betterment of the department and the perfection of the work.

JAN'Y, 1895. W. A. POWERS.

SPECIAL REPORT

OF THE

NEW YORK CITY STEAM BOILER INSPECTION AND ENGINEERS' BUREAU, JAN. 1, 1895,

ON

BOILER INSPECTION AND THE LICENSING OF ENGINEERS.

In the last annual report from this bureau the inadequacy of the present method of boiler inspection was commented

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There are but few engineers in New York City who have not met Sergeant Washington Mullin, Chief of the Boiler Inspection and Engineer's Bureau, of New York City. Thousands of engineers know him at sight. For the benefit of those who have not had the pleasure of meeting him we herewith present a brief sketch of his active life:

Officer Mullin was born in the City of Philadelphia, Sept. 29th, 1837. His parents removed to New York City when he was but eight years of age, and he attended the public schools until he had reached his sixteenth year, when he was apprenticed in the engine and machine works of Abraham Van Ness, where he was working at the breaking out of the war. Young Mullin was among the first to respond to his country's call, and assisted in organizing Company "E," 73d N. Y. Volunteers. He participated in all of the engagements in which his brigade took part; was promoted to first lieutenant, and honorably discharged September, 1864; was appointed to the Police Department, New York City, September, 1864, promoted to roundsman Oct., 1865, to sergeant 1868, and subsequently assigned as Chief of the Boiler Inspection and Engineer's Bureau, February, 1882.

Schooled as a soldier, he is a strict disciplinarian; uses discretion in the examination of the many thousand engineers who come before him annually to pass the examination preparatory to taking out the engineer's license required by law; never discriminates, treats all applicants alike, shows no favoritism, and the engineer who obtains a license must pass the necessary examination in a satisfactory manner, proving his ability to take charge of and operate a steam plant. The competent have nothing to fear in Sergeant Mullin--the ignorant, incompetent and intemperate are always rejected.

The Engineer's List, Jan. '95.

upon, and recommendations made for a change in the laws to improve the system, to the end that the protection to life and property be made more secure, and the dangers from such casualties as boiler explosions reduced to a minimum.

While there were several bills presented to the last Legisla ture, touching upon the matter of boiler inspections and licensing of engineers, none seemed to meet with approval, and all failed of passage.

Therefore, it is again respectfully submitted that, in consequence of the danger to life and property, attendant upon the operation of steam boilers, it would seem that no difficulty should be encountered in the endeavors made to have them legally regulated as to their proper and careful construction and inspection, as well as to the licensing of those who are to have charge and operate them, more especially in localities which are thickly populated, and where an explosion of a steam boiler means dire disaster.

As a matter of comparison between the different places in the United States, where there are inspection laws and where no legal supervision exists, it will be noted that the casualties resulting from boiler explosions are as one to a hundred. If the importance of this matter was properly and intelligently impressed upon the consideration of those selected to make the laws, and more stringent safeguards were drawn around the laws and ordinances now in force, a much greater percentage would be shown in favor of legal supervision.

The boiler-inspection laws now in operation in the cities of New York and Brooklyn, as far as the particular method of inspection is concerned, are the same as those existing in

1862, when not more than 2,000 steam boilers were operated in the then metropolitan district, comprising the counties of New York, Kings, Richmond and parts of Queens and Westchester, while now there are upward of 8,000 boilers in use in the City of New York alone.

At the time mentioned, and for some years after, the average pressure used to operate steam boilers was about fifty pounds to the square inch, whereas, at present, owing to the advancement and improvements made in machinery and other devices necessary for steam to operate have been so great that the average pressure carried will equal 100 pounds to the square inch, and yet, withal, no legal advancement has been made in the matters regulating the testing and inspection of boilers. To be sure, reputable manufacturers and builders of steam boilers take the necessary precaution in building boilers required to withstand this extra demand for increased pressure, but it is to guard against that class of firms who construct cheap work, taking chances on the safety and security of the boilers they make, that more rigid laws should be enacted.

Such laws should provide that every maker of a boiler should issue or give a certificate, setting forth the quality and thickness of the material used, its guaranteed tensile strength and ductility, the pressure per square inch the boiler is designed to carry, and every particular concerning its construction, and that in the absence of such certificate the tensile strength of the material should be calculated at 40,000 lbs. for iron and 50,000 lbs. for steel plates, when determining the safe working pressure.

The strength and security of a boiler should be determined by a series of calculations, based upon established rules, upon its various parts, and, when the workmanship and material is found to be of good quality, a factor of five should be the standard used to determine the safe working pressure to be allowed.

But, in the matter of inferior workmanship or inferior material, authority should be given the inspector to either condemn the boiler or increase the factor to a degree that would insure the utmost safety in the operation of the boiler. Then, again, every boiler should be subjected to a hydrostatic test before put in actual operation, such a test to be made at least once every year thereafter, and in the following manner:

The boiler to be filled entirely with water, a fire lighted in the furnace, and the temperature of water brought to at least 150 degrees of Fahrenheit, when the boiler should be subjected to a hydrostatic pressure of one and one-half times the steam or working pressure to be allowed per square inch. The inspector, after applying the hydrostatic test, should go inside the boiler and make a thorough examination of every part of the same, and, if the test is not satisfactory, the defects should be made good, and the boiler re-tested.

In water-tube boilers, constructed to carry 150 lbs. or more, where the factor of safety is generally above seven, the pressure should be one and one-quarter times the working pressure to be allowed, for the reason that pressure above 225 lbs. will rupture calking in longitudinal seams of steam drums.

In determining the working pressure for boilers that have been several years in use, the inspector should take into consideration the age and condition under which it has been operated, as well as the thickness, original strength, efficiency of riveted joints, etc., and make calculation between what was its safe working pressure when new, and the pressure now desired, and he should make due allowance for deterioration, and, if necessary, drill holes to properly determine its thickness.

All boilers should have a composition valve or cock placed in the feed line, between the check valve and the boiler, so as to permit of overhauling the check when steam is up, if necessary. All pipe connections of over one inch internal diameter should be attached to the boiler by a flanged joint, riveted or bolted. Each boiler should have three gauge cocks and a water glass, and the gauge cocks and water column should be connected directly to the boiler with at least one-inch pipe, the lower water pipe to be tapped near the bottom of the boiler, and the upper steam pipe connected at the top of the boiler, and as far away from whére the main steam pipe is connected as is practical.

No other connection should be allowed to be taken from it. A blow cock should be placed at the bottom of the lower water pipe. The bottom gauge cock should be placed at least two inches above the highest heating surface, and the other cock placed in proper proportions, so as not to unduly reduce the intended steam space.

Each boiler should have a steam gauge that would correctly indicate one-and-a-half times the working pressure

allowed, and one safety valve of sufficient capacity, when open, to carry off all the steam the boiler could generate with all the other valves closed.

The blow-off pipe on horizontal tubular boilers, when attached to the back connection or combustion chamber, should be of ample size, but not to exceed two inches internal diameter, and should be of extra heavy pipe, with malleable fittings, and protected from the intense heat by a metal sleeve or other covering, and, in the absence of such covering, there should be a circulating pipe connected with the upper part of the boiler to give good circulation and eliminate the danger attending the dead end between the blow cock and boiler. There should also be a surface blow-off.

All high pressure boilers of the vertical or locomotive style should have a fusible plug placed in the crown sheet.

Boilers should have two ways of feeding—by a steam pump and by an injector; pumps to be used only when hot water is available or the injector out of order. When two or more boilers are connected, the inspectors should give particular attention to the connection in the main steam pipe, and see that due allowance is made for expansion.

That a proper record of each boiler may be kept, and that it could be at all times easily identified, a plate, bearing the official record number of the boiler, should be securely and permanently fastened to the boiler in a conspicuous place.

It should be made the duty of engineers in charge of steam boilers, to blow, or cause to blow, at least once each day, the safety valve to insure its readiness for use, and should a

safety valve be found, at the annual inspection, to have been tampered with or out of order, the certificate of the person in charge should be suspended or revoked.

Provision should also be made that would require an engineer to go inside his boiler, at least once in three months, to cleanse the same, and see that no accumulation of scale or corrosion had taken place. By this means the property of his employer will be protected, the life of the boiler prolonged, and the loss to life and property averted.

These are mentioned as some of the provisions that should be embodied in a law which, when drafted, would cover the necessary requirements more in detail, and which would surely meet the approval, and ultimately result to the benefit, of owner, steam user, engineer, and everybody in any way concerned or interested in the use of steam, or the safety to life and property. Respectfully submitted,

WASHINGTON MULLIN.

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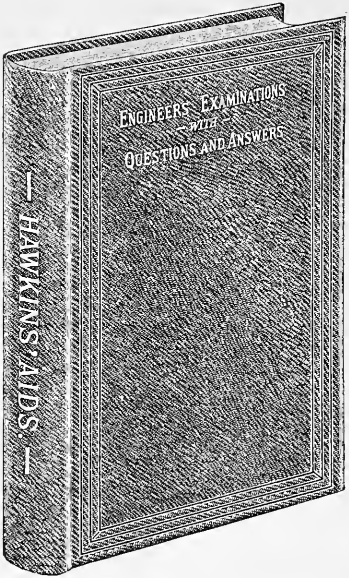

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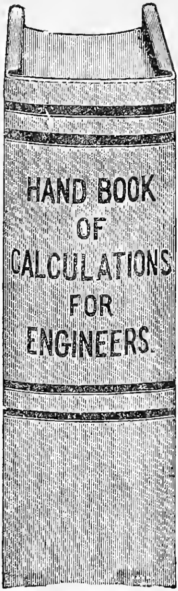

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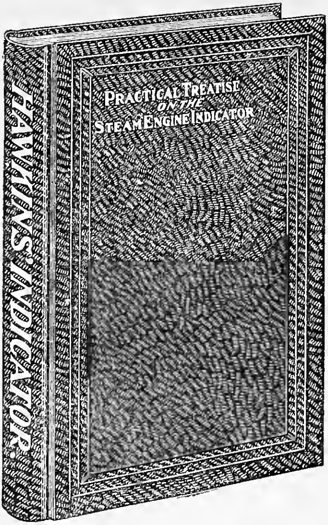

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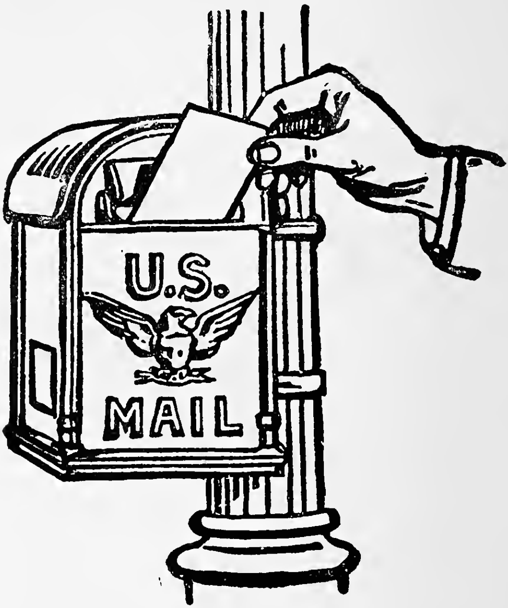

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